THE FIRST CaSSIS OBSERVATIONS OF MARTIAN RECURRING SLOPE LINEAE: IMPLICATIONS FOR THEIR ORIGIN AND EVOLUTION

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Introduction: Recurring Slope Lineae (RSL) are narrow, dark features that often source from bedrock outcrops and incrementally lengthen down warm Martian steep slopes [1]. In general, most RSL form when temperatures are warm, typically in local spring and summer, fade in cold seasons, when temperatures drop, and recur annually at the same locations [1]. Multiple models have been proposed to explain their origin, but a definitive explanation is still missing. The temperature dependence of RSL activity and their spatial correlation with some multi-scale fractures [4] suggests that they may originate from liquid triggered flows [1,2,5,6,7], possibly powered by groundwater sources [4,6,7] while other studies favored dry mechanisms involving granular flows [3,8-11]. Other hypotheses suppose that water plays an indirect role in RSL activity. According to [12], moisture may serve to stabilize steep slopes in cold seasons, which flow when drying during warm seasons. In addition, [13] proposed that subsurface brine activity can create surface collapse features, perhaps initiating RSL when on steep enough slopes. RSL observations are now possible with the Colour and Surface Stereo Imaging System (CaSSIS, [14]) on board the ESA ExoMars Trace Gas Orbiter mission (TGO), which provides color images of the surface of Mars in four bands at 4.6 m/px.. The 74° inclined orbit of TGO allows CaSSIS to image a given location of Mars at different local times, providing the unique opportunity of imaging RSL sites in the morning. These observations are of critical importance in understanding the nature of RSL, indeed: if these features are related to liquids via deliquescence, then they should be darker in the early morning. If they are caused by melting of shallow subsurface ice, then they should be darker during afternoon. On the contrary, no differences between morning and afternoon observations are expected for dry flows. In this study we present the first observations of RSL performed by CaSSIS during the local morning and compare them with High Resolution Imaging Science Experiment (HiRISE,[15]) observations acquired one month earlier in the afternoon. In particular, we search for any difference in their overall activity and relative albedo between morning and afternoon images. We analyze the thermal conditions of the surface and shallow subsurface to assess whether temperatures would allow either melting of brines or deliquescence of salts at the time of the CaSSIS observation.

Data: The study region is the central peak of Hale crater (−35.7° N, 323.5), where some of the biggest RSL have been discovered so far, making it an ideal site to be investigated with CaSSIS. It was imaged by HiRISE on 27/01/2019 at 2 : 08 PM local time and with a L_s = 331.5° and later by CaSSIS on 26/02/2019 at 11 : 13 AM local time, with a Ls = 347.4°, in stereo mode and with the near infrared (NIR), red (RED), panchromatic (PAN) and blue (BLU) filters [14]. To study the thermal environment of RSL at Hale crater, Nighttime infrared Thermal Emission Imaging System (THEMIS,[16]) observations within ± 5° of Ls of the CaSSIS observation were also used.

Methods: we identified all RSL that were resolved on both the HiRISE and CaSSIS images.

General properties: we compared the areal extent of each identified RSL between the morning and afternoon images. When a significant change could be detected, we labeled them as "changed", otherwise as "static". We computed slope and aspect for all the identified RSL using a DTM of Hale crater, publicly available at https://www.uahirise.org/.

Relative albedo: to assess whether RSL are darker, and thus potentially wetter, during morning with respect to afternoon, we measured the relative albedo of a sample of RSL with respect to neighboring, RSL-free slopes for both the CaSSIS and HiRISE images, adapting the techniques described in [11,17].

Thermal analysis: we derived a thermal inertia map of Hale crater at 100 m resolution by processing THEMIS nighttime infrared observation through the MARSTHERM web interface [18]. The map was used

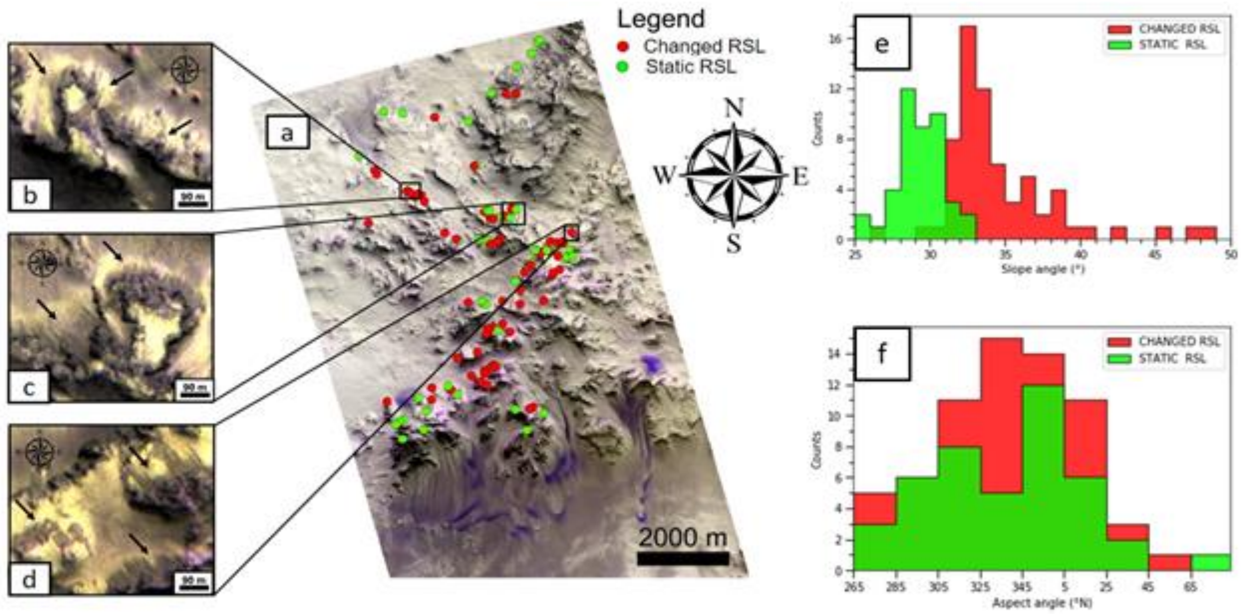

Figure 1 a) CaSSIS color composite of the RED, PAN, and BLU filters showing the location of all identified RSL and their classification in terms of "changed" (red) and "static (green). b,c,d) Examples of identified RSL as viewed through CaSSIS. e) Slope and f) aspect distributions for "changed" (red) and "static" RSL.

as input for the thermal model of [19] to simulate diurnal temperature profiles at the surface and shallow subsurface at Hale crater.

Results and discussion: we identified a set of 112 RSL, resolved on both images and depicted in figure (1). No aspect differences were detected between "changed" and "static" RSL. Instead, the former are found only on slopes > 32° while the latter on slopes <32°, consistent with dry granular flow behavior. Relative albedo analyses shows no differences between morning and afternoon relative albedos, again consistent with dry granular flows. Thermal analyses indicate that formation of liquids through deliquescence of salts or melting of shallow subsurface ice could occur during the late morning CaSSIS observation. Yet, no observable counterpart of these processes have been detected. Overall, our analysis suggest that RSL are best explained as dry, granular flows. Details on RSL mapping, relative albedo analysis and thermal modeling will be given 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.

References: [1] McEwen, A.S. et al., 2011. Science, 333, 740-743 [2] Stillman, D.E. and Grimm, R.E., 2018. Icarus, 302, 126-133 [3] Vincedon, M. et al., 2019. Icarus, 325, 115-127 [4] Abotalib, Z.A. and Heggy, E, 2019. Nat Geo. 12, 235,241 [5] McEwen A. S. et al., 2014 Nat. Geo., 7, 53-58 [6] Stillman, D.E., et al., 2017a. Icarus, 285, 195–210 [7] Stillman, D.E., et al., 2016. Icarus, 265, 125–138.[8] Edwards, C. S. and Piqueux, S., 2016. Geophys. Res. Lett. 43, 8912– 8919, [9] Dundas, C., et al., 2017. Nat. Geo,7, 903–907 [10] Schmidt, F. et al., 2017, Nat Geo,10, 270–273 [11] Schaefer, E. et al. (2019) Icarus 317, 621-648. [12] Shoji, D. et al., 2019. arXiv e-prints, arXiv:1909.06144 [13] Bishop, J. L. et al, 2019, Lunar and planetary science conference (p. 1188). [14] Thomas,N. et al., 2017,SSR, 212,1897–1944 [15] McEwen, A. S., et al., 2007, J.G.R., 112,E05S02 [16] Christensen, P. R. et al., 2004,Space Sci. Rev., 110(1), 85-130 [17] Daubar, I. J. et al., 2016 . Icarus, 267, 86-105 [18] Putzig, N. E. et al., 2013. Agu fall meeting abstracts (Vol. 2013, p. P43C-2023) [18] Schorghofer, N., Levy, J., & Goudge, T. (2019 JGR: Planets, 124, 2852– 2862