EPSC Abstracts
Vol. 12, EPSC2018-171, 2018
European Planetary Science Congress 2018

Spectral clustering applied on the ExoMars/CaSSIS simulated imagery dataset

Maurizio Pajola (1), Livio L. Tornabene (2), Frank P. Seelos (3), Giuseppe A. Marzo (4), Alice Lucchetti (1), Gabriele Cremonese (1), Antoine Pommerol (5), Patricio Becerra (5) and Nicholas Thomas (5)
(1) INAF, Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, 35122, Padova, Italy (maurizio.pajola@oapd.inaf.it), (2) Centre for Planetary Science and Exploration/Department of Earth Sciences, University of Western Ontario, London, Ontario N6A5B7, Canada, (3) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, (4) ENEA C. R. Casaccia, 00123, Roma, Italy, (5) Physikalisches Institut, University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland

Abstract

The Colour and Stereo Surface Imaging System (CaSSIS, [1]) is the scientific camera onboard the ExoMars Trace Gas Orbiter spacecraft. This instrument has three main aims: 1) to characterize possible surface/subsurface sources for methane and other trace gases, 2) to investigate dynamic surface processes that may contribute to atmospheric gases, and 3) to certify and characterize safety and hazards such as rocks and slopes, associated with candidate landing sites for ExoMars 2020 and other future surface missions [1]. To accomplish such goals, CaSSIS couples stereo topography and color observations with a spatial resolution of 4.6 m. The instrument has a suite of four filters (band 1 centered at 0.499 µm, band 2 at 0.675 µm, band 3 at 0.836 µm and band 4 at 0.937 µm) that provides the means to discern the variations in the oxidation state of iron-bearing minerals and phases (Fe^{2+}, Fe^{3+}) [2].

Since its arrival at Mars on October 2016, the ExoMars spacecraft underwent an 18 months-long aerobraking phase that ended in April 2018. During this period, a CaSSIS-simulated imagery dataset was prepared and published [2] to fully assess both the colour capabilities and potential for spectral measurements of the instrument once the nominal mission begins (first weeks of May 2018). This dataset is characterized by two types of simulated products: the first is a partial simulated colour product (181 cubes) that provides the spectral bands of CaSSIS by convolving the VNIR spectral information obtained by the CRISM instrument [3] with the CaSSIS instrument response functions. These products maintain the spatial scale of the CRISM input cubes, i.e. 18-36 m/pixel (hence the "partial" designation). The second type are fully simulated products (33 cubes), produced by merging the partial simulated colour cubes with a 32-bit radiometrically calibrated I/F panchromatic image from CTX [4] that is oversampled from 5-6 m/pixel to the nominal pixel-resolution of CaSSIS (4.6 m). As such, the fully simulated CaSSIS cube provides both the simulated colours and the spatial scales of an unbinned CaSSIS cube.

For this specific work, we decided to exploit some of the fully simulated colour products that cover the three final proposed landing sites for the NASA Mars 2020 rover (Jezero crater, N-E Syrtis and Columbia Hills) and the two finalists for the ExoMars 2020 rover (Oxia Planum and Mawrth Vallis). We focus on these targets to support the characterisation of landing sites (goal no. 3 in [1]). Moreover, these areas will be repeatedly observed by CaSSIS soon (targeting mode anticipated for late summer 2018) to see if any color and/or morphological changes may occur before the rover landings; hence, we provide high spatial scale analyses of simulations to expedite analysis of the actual CaSSIS data and provide pre-landing context.

We used the unsupervised K-means partitioning algorithm developed by [5] to investigate the spectral variability across the areas selected. This technique has been extensively validated using different spectral data sets on different areas of Mars [5-7], Mercury [8], Iapetus [9,10], Phobos [11] and Charon [12]. The statistical partitioning identifies different clusters on the study areas, based on the different exposed mineralogical signatures (see for example the Jezero crater case, Fig. 1). Each resulting cluster is characterized by its average and associated standard deviation. In addition, the geographical information of each spectrum is maintained in the process, hence the resulting clusters can be located on the studied surface and correlations with

geographical features can be investigated.

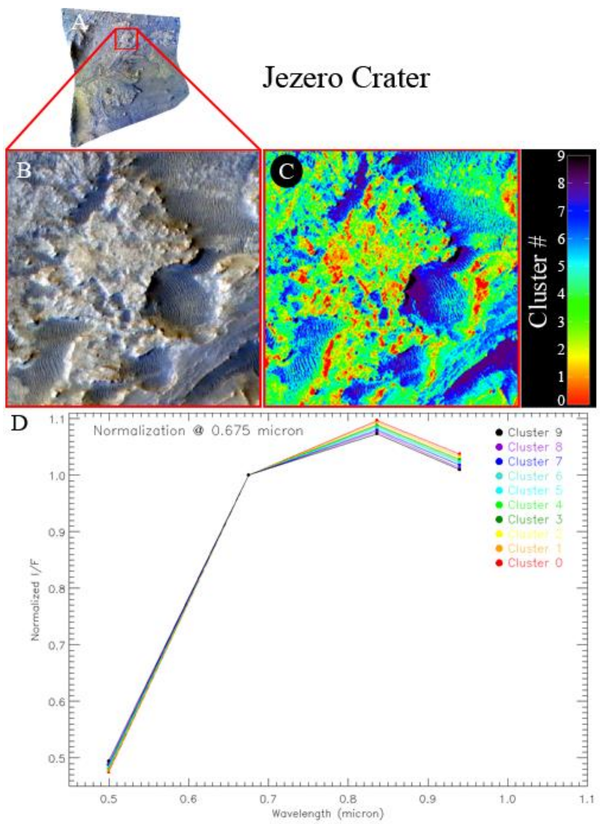

Fig. 1: A) Context image of the Jezero delta. This is one of the full simulated products called *cassis_sim_c_05c5e_x_002387_1987_corr_if_nn_4band_composite*. B) The location on the Jezero delta where we applied the spectral clustering. C) The 10 clusters identified on the surface. D) The spectra of all clusters identified in C.

To highlight the different absorption strengths observable from the ferrous (Fe^{2+}) or ferric (Fe^{3+}) iron spectra, we normalized all spectra at 0.675 μm (band 2). In this way, it is possible to highlight the inverse relationship between the behaviours of bands 3, 4 and band 1, i.e. in general, a deeper absorption at band 4 equates to a shallower absorption at band 1, and it appears to be sensitive to the presence of ferrous (or mafic) compositions, while the opposite is true for ferric altered compositions. This spectral trend is what we observe in our example on the Jezero delta (Fig. 1). A careful analysis shows that variations in the band 1 and 3,4 absorptions are not only related to the exposure of ferric and ferrous materials but also due to the physical mixing of these Fe-bearing components. Surface dust, which bears ferric Fe, also contributes to a band 1 absorption. Mixing can be readily identified in our analyses as concentric gradients between spectral clusters. Deeper band 1 and shallower band 4 absorptions correlate with the inverted fan deposits (clusters 0 to 4); while clusters 5 to 8 are mainly related to basaltic mobilized material in the form of aeolian bedforms preferentially trapped in low-lying topographic areas. Cluster 9 is associated with the shadowed regions.

The simulated CaSSIS cubes provide spectral clusters at an unprecedented scale and coverage (e.g., aeolian bedforms are well resolved, so these products could be used for engineering constraints such as rover traverse ability). Similar spectral trends are observed on all five landing sites. Therefore, this analysis shows that when the spectral clustering technique is applied on the first CaSSIS color cubes, it will be an important tool to help distinguish different mineralogical deposits on Mars.

Acknowledgements

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] Thomas, N. et al., 2017. Space Sci. Rev. 212, 1897–1944. [2] Tornabene, L.L. et al., 2018. Space Sci. Rev. 214, 18. [3] Murchie, S. et al. 2007. J. Geophys. Res., Planets 112(E5), E05S03. [4] Malin, M.C., et al. 2007. J. Geophys. Res. 112, E05S04 (2007) [5] Marzo, G., et al., 2006. *J. Geophys. Res.* 111. E03002. [6] Marzo, G., et al., 2008. *J. Geophys. Res.* 113. E12009. [7] Fonti, S., Marzo, G.A., 2010. *Astron. Astrophys.* 512 (A51), 6 pp. [8] Lucchetti, et al., 2017. *48 Lunar and Planetary Science Conference*, 1964. [9] Pinilla-Alonso, N., et al., 2011. *Icarus* 215 (1), 75. [10] Dalle Ore, C., et al., 2012. *Icarus* 221 (2), 735. [11] Pajola, M. et al., 2018. *Planet. Space Sci.* 154, 63-71. [12] Dalle Ore, C., et al., 2018. *Icarus* 300, 21–32.