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Compositional analysis of the MarSCoDe's LIBS data from Zhurong rover

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Laser-induced breakdown spectroscopy (LIBS) has been a versatile technique for geochemical analysis of the Martian surface. Zhurong rover of China's first Mars mission is carrying the Mars Surface Composition Detector (MarSCoDe) with LIBS capability [1]. 44 Martian targets were probed by LIBS before the rover's hibernation. Here, we present our current effort to qualitatively and quantitatively analyze their compositions.

The qualitative clustering analysis of LIBS spectra was conducted through first independent component analysis (ICA) [2] and then t-distributed stochastic neighbor embedding (t-SNE) [3], reducing the dimensionality while maintaining the neighborhood relationships. The resultant 2-dimensional representations (Fig.1) demonstrated a clear clustering of Mars targets between Fe-rich and silicates standards, with one Mg-rich target (Sol 45-1) and three missed shots (in Outliers).

Quantification modeling of MarSCoDe LIBS data faces two major obstacles: 1) the small (93) initial dataset [4]; 2) the uncertain plasma excitation condition on Mars [5]. For 1), we have purposed the multivariable probabilistic major element composition (PMEC) models [4] that dynamically address the uncertainty from the model knowledge. For 2), a LIBS quality index (LQI) [5] was developed to evaluate the excitation of targets.

Nine targets (one soil, two rocks, and six rock surficial targets) with relatively good LQIs were selected for initial PMEC analysis. Early investigation hypothesized that the thickly-covered (mm-scale) rock surfaces were built up by the cementation of saltated soil aggregates to the rock surface[6], thus we performed de-mixing for the surficial targets against soil for verification. Derived "compositions" are highly enriched in Si, Na, and K and depleted in Mg (Fig. 2), which may represent a compositional drift probably caused by either the enrichment of cementing agents, or physical sorting during the saltation. Further study will concern the processes leading to the current surficial build-ups.

[1] Xu et al. (2021) *Space Sci. Rev.*, 217. [2] Forni et al. (2013) *Spectrochim. Acta B At. Spectrosc.*, 86. [3] van der Matten and Hinton (2008), *J. Machine Learning Res,* 9. [4] Chen et al. (2022) *Spectrochim. Acta B At. Spectrosc.*, 197. [5] Chen et al. (2023) *LPSC,* 1480. [6] Chen et al. (2023) *BEACON 2023*.

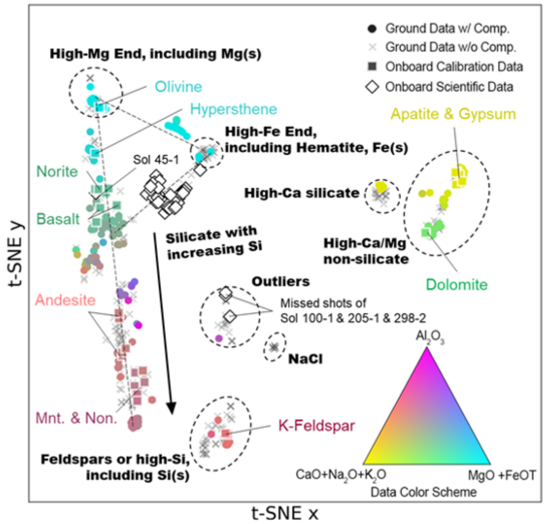

Fig. 1 2-dimensional representations for MarSCoDe LIBS data from Mars (in squares and diamonds) and pre-flight laboratory experiment (in circles and crosses). The x and y axes represent qualitative measures of neighboring relationship by t-SNE. The data of known compositions are colored according to their coordination in the A-CNK-MF ternary. Mnt. & Non.: montmorillonite and nontronite onboard calibration targets.

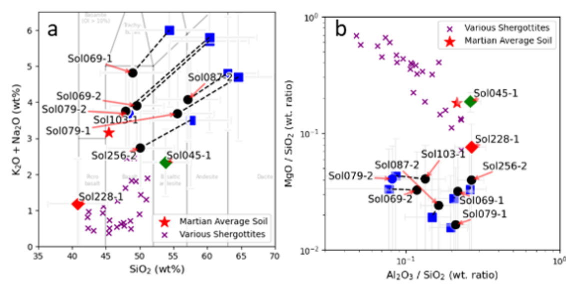

Fig. 2 PMECs results of selected Mars targets. Symbology: 1 soil (Sol228-1) in red diamond; 2 rocks in green diamond (for Sol045-1) or in blue circle (for Sol079-2); 6 surficial targets in black circles with connected blue squares (results of de-mixing against Sol228-1). Martian average soil from Taylor and McLennan, 2009; Shergottites compositions from The Martian Meteorite Compendium, NASA.