µLIBS: A MICRO-SCALE ELEMENTAL ANALYSER FOR LIGHTWEIGHT *IN SITU* EXPLORATION.

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Need for microanalyses: Analysis at submillimeter scale, or microanalysis, is the next step forward in planetary exploration. On Mars, a diversity of rock micro-textures have now been observed *in situ*, sedimentary, igneous or of uncertain origin [1]. Yet the lack of associated chemical micro-analysis prevents further understanding of geologic units. Indeed, microanalyses associates chemical composition with submillimeter scale fractures or void fills, as well as matrices, crystals, mesostasis and alteration phases in igneous rocks or individual grains, concretions and cements in fine-grained sedimentary rocks, all crucial to reconstruct the processes that generated these features.

Laser Induced Breakdown Spectroscopy (LIBS) is a technique that uniquely provides elemental abundance at submillimeter scale on naturally exposed rocks while removing surface dust. It can quantify the abundance of major elements (Si, Fe, Mg, Al, Ca, K, Na, Ti) in addition to volatiles relevant to the detection of organics (C, H, N, O, P, S) as well as other light and/or minor elements (Li, Sr, Cr, Rb, Mn...). As it documents elemental composition down to mineral grain size it is also able to detect mineral end-members and infer mineral assemblages in addition to bulk chemistry.

Technology and heritage: LIBS is now widely used in the laboratory for microanalyses, and on Mars a decade of experience with the ChemCam instrument [2], and now SuperCam [3,4], has proven the technique's reliability and capability to analyze rocks at a submillimeter scale for geological investigations. Miniaturization of LIBS systems has recently matured and now a set of handheld commercial devices ≤ 2 kg (battery and gas purge included) are available for geochemical analyses [5]. Based on ChemCam and SuperCam subsystems heritage, we propose a new ≤ 1.5 kg instrument to perform LIBS analyses on Mars' surface with architecture closer to handheld devices.

Foreseen capabilities: µLIBS will operate at a distance of 20 to 50 cm enabling significant mass reduction compared to ChemCam and SuperCam designs. Importantly, it will include a 2-axis actuated scanning mirror for the analysis of multiple targets within an area below the platform (Fig. 1). This mechanism will enable precise pointing of the 50 µm focused laser spot to perform closely-spaced grid observations on areas < 1 cm². It also includes a remote micro-imager to provide dust-free micro-textures with elemental grid overlaid. µLIBS laser can operate at 10 Hz and lower energy, making a typical 10x10 grid observation under an estimated 20 min duration or a 30x30 grid under 1 hour. These 100 to nearly 1000 grid points will help detect minor phases down to 1% and 0.1% of the rock and map their distribution.

Conclusions: µLIBS can provide micro-scale elemental analyses with a science return similar to contact instruments, for lower cost as it can operate remotely with high-precision from a mobile platform undercarriage with no need of arm deployment nor platform turret. It is overall low risk (heritage-based), low mass, and low cost with significant improvements in terms of accuracy and rapidity.

References: [1] Mangold N. et al. (2017) *Icarus* **284**, 1–17. [2] Maurice S. et al. (2016) *J. Anal. At. Spectrom.* **31**, 863–889. [3] Maurice S. et al. (2021) *Space Sci. Rev.* **217**, 47. [4] Wiens R. C. et al. (2020) *Space Sci. Rev.* **217**, 4. [5] Senesi G. S. et al. (2021) *Spectrochim. Acta Part B At. Spectrosc.* **175**, 106013.

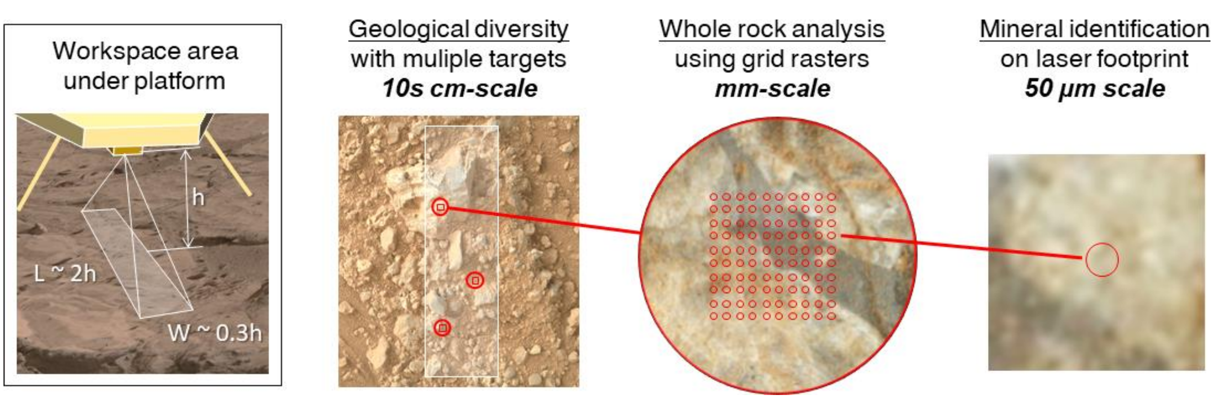

Figure 1: µLIBS provides a nested multi-scale analysis, from the selection of several targets in a decimeter scale workspace to the 50 µm footprint of laser spots following grid rasters. Example workspace: Curiosity rover, sol 387, MAHLI standoff distance at 25 cm on target Ruker.