What ChemCam's first shots tell us about martian dust? J. Lasue[1], A. Cousin[1], P.-Y. Meslin[1], N. Mangold[2], R.C. Wiens[3], O. Forni[1], O. Gasnault[1], W. Rapin[1], S. Schröder[1], A. Ollila[2], G. Berger[1], E. Dehouck[1], J. Johnson[4], S. Le Mouélic[2], S. Maurice[1], R. Anderson[5], D. Blaney[6], N. Bridges[4], B. Clark[7], S.M. Clegg[3], C. D'uston[1], C. Fabre[8], W. Goetz[9], N. Lanza[2], M. B. Madsen[10], J. Martin-Torres[11], N. Melikechi[12], A. Mezzacappa[12], H. Newsom[13], V. Sautter[14], M.P. Zorzano[11] and the MSL Science team
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Introduction: ChemCam is a Laser-Induced Breakdown Spectroscopy (LIBS) instrument on-board the NASA Mars Science Laboratory rover that has been exploring Gale Crater, Mars for the past four years. A pulsed infrared laser is focused to the target of interest and heats it up to about 10000 K generating a plasma of electrons, ions and atoms, the light of which is collected by a small telescope and analyzed by spectrometry [1, 2]. Thanks to its ability to analyze the composition of geological targets at a distance from the rover and without initial preparation, ChemCam is an ideal survey instrument to detect changes in composition in the environment of the rover. Over the four years of exploration at Gale, ChemCam has acquired more than 400000 spectra and analyzed around 13000 different locations. During a typical sample analysis, ChemCam samples 30 shots per target, but in few cases, some depth profiles were executed with up to 600 shots at the same location. Each shot on target removes just few nanograms of material. The first five shots are contaminated by martian Aeolian dust deposited on the targets and are systematically removed from the quantification analysis of the rock targets. The composition of the first few shots is characteristic of the global martian fine dust, which covers the entire planet [3] and contributes to the local geology analyzed by MSL [4, 5]. This work compiles the ChemCam first shots taken on calibration targets and martian targets over the four years to refine the composition of the Aeolian fine dust detected by ChemCam and assess any possible time variations.

Martian fine dust deposition: A global component of fine dust aerosol can be mobilized by aeolian processes on the surface of Mars and deposits constantly on the Mars rovers, while being sometimes removed by the action of wind. As shown in Figure 1, very small dust particles deposit on the rover and affect the detection of UV sensors. In analyzing the first ChemCam shot, we analyze dust mostly from airborne origin and recent deposition which should consist of a typical grain size distribution around 1-2 µm [e.g. 6].

ChemCam passive spectroscopy [7] has also been used to assess the variations in dust cover from the rover paint target located amongst the ChemCam calibration targets (CCCT). The passive spectroscopy presents reddening of the rover paint CCCT with time that indicates deposition or removal of the dust particles on its surface.

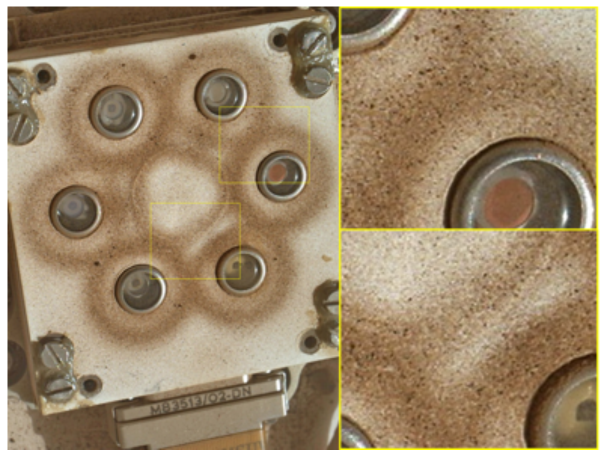

Figure 1: Sol 323 MAHLI image of the UVS, taken after the passage of the regional dust storm. Dust grains sticking to the magnetic rings with different albedos and colours are seen.

Martian fine dust composition: Since the beginning of the mission, every first shot analyzed by ChemCam has presented a significant compositional contribution, always identical, that is representative of a global martian component. This contribution, appearing in the first five shots, is routinely removed from the analysis of the targets of ChemCam to get the composition of the underlying rock [8]. The consistency of this first spectrum gave the opportunity for the ChemCam team to improve the distance correction for the ChemCam data [9, 10].

The martian fine dust component spectrum can be retrieved using the well characterized ChemCam calibration targets (CCCT) on-board the rover, by subtracting their spectrum from the first shot spectrum. However, due to matrix effects in the plasma when dust and underlying targets are ablated together, it is not easy to quantify the spectra thus obtained, even though they qualitatively are very similar to the ones of very fine soil [11]. This method has also the drawback of generating large variations in the quantification with a small statistics of data points (<10).

For compositional quantification, we therefore prefer to consider a statistical average of the dust deposited on martian targets which presents typically less variations and a thicker layer of deposited dust. In that case, we can make use of about 8500 spectra available over 1500 sols. A part of the dataset (between sols 805 and 980) cannot be used as during that time, the continuous laser diode used for LIBS focalization was not operating and focalization of the laser was determined by the intensity of the LIBS signal, implying that every first shot on the target was out of focus. A new focalization procedure based on imaging was introduced after sol 980, and we include in our analysis the first shot data taken after this date.

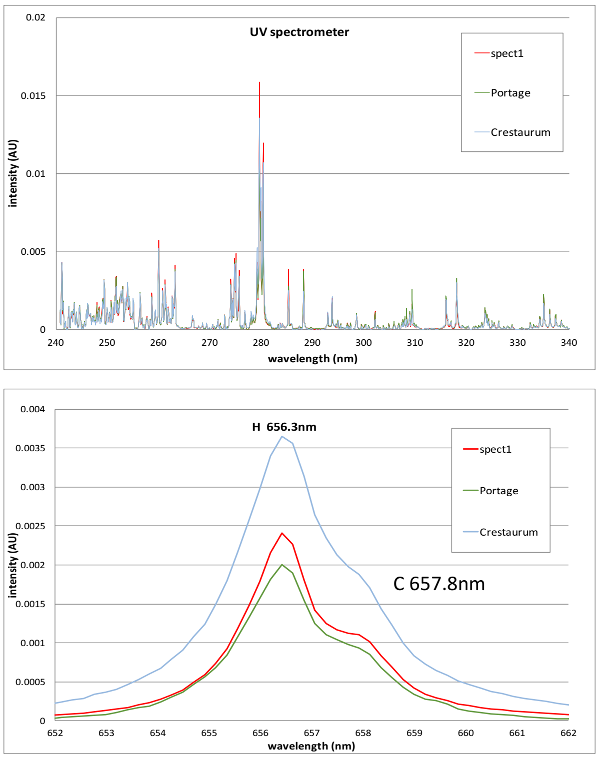

Figure 2: Comparison between the averaged ChemCam first shot and the Crestaurum and Portage soils (sol 74 and sol 89) shown a. for the UV spectrometer and b. for the hydrogen peak (656.3nm).

Figure 2 shows the superposition of the average ChemCam first shot over the mission and the ChemCam analysis of typical soils such as Crestaurum (sol 74) or Portage (sol 89). This indicates a similar content in major elements and hydrogen. In this way, all the major and some minor elements are detected. The line ratios are consistent with a basaltic composition similar to the one detected globally on the planet [3-6]. Every ChemCam first shot presents a strong H line, indicating that this fine dust is a contributor to the H content of the martian samples also detected by the SAM instrument at the level of 1.5-3 wt.% [4, 12, 13]. This in turns means that this fine dust also contains part of the hydrated amorphous phase of the soil.

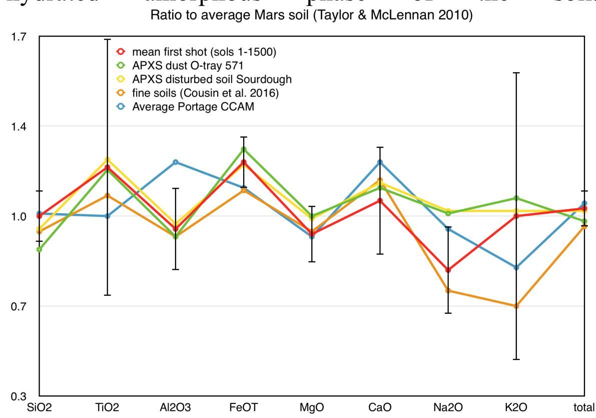

Figure 3: Mean 1st shot ratio to average Mars soil with standard deviation [14] and comparison with ChemCam fine soils [5, 15] and APXS dust measurements [16].

As shown in Figure 3, comparison between the fine dust component and typical fine soils, indicates a similar content in major elements with soils analyses from ChemCam and dust deposits from APXS (normalized with H2O=2wt.%) [16]. Alkali are variable while the minor elements Ba, Sr, Rb, Li are detected in quantities similar to previous soils analyses. Mn and Cr appear to have larger peak areas than typical ChemCam soils. S and Cl peaks are detected in agreement with APXS enrichment of S and Cl in dust [16].

Conclusion: The chemical composition of the martian fine dust component can be analyzed with the ChemCam instrument and compared to other measurements. We now have at our disposal a large dataset covering four years of survey which indicates potential variations of the dust composition with time, which will be further assessed.

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