

ChemCam Hydrogen Detection in Soils and Dust along the Curiosity rover traverse

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Introduction

The ChemCam suite [1, 2] on NASA's Mars Science Laboratory (MSL) rover combines a Laser-Induced Breakdown Spectroscopy (LIBS) instrument with a Remote Micro-Imager (RMI), providing elemental analysis of soils and rocks together with pre- and post-LIBS context images of the target. One of the main advantages of LIBS is its ability to detect light elements such as hydrogen, which may indicate the presence of water, a key criterium for habitability. Hydrogen is observed in most of the ChemCam target spectra, usually with lower signal intensity in rocks than in the soils [3, 4]. A hydrated dust layer appears to cover the martian landscape, as documented by analysis of the first shots in multi-shot (typically 30 laser pulses) ChemCam spectra acquisition [5, 6].

We present hydrogen signal-to-background ratios (SBRs) obtained from a uniformly obtained data set along the traverse during 270 sols. We focus on the hydrogen signal of the first shot spectra of dust on rocks and on the variation with shot number and depth of the hydrogen signal in the soils, expanding on our previous investigations [3-5].

Data Acquisition and Analysis

"Blind targets" are defined as targets observed by ChemCam after the rover has moved and information such as new images and the relative position of potential targets are not yet available for planning the next sol activities [7]. The laser focuses on the right side of the rover and probes the martian ground at 3 m distance using a uniform raster (e.g. 10 positions with 30 shots each in a row). By default, a so-called dark spectrum (measured from the same location and for the same integration time as the active LIBS spectrum but without lasing) is taken at every position before (DS1) and after (DS2) the laser is fired. The dark spectrum

accounts for reflected sunlight on the martian target as well as pattern noise and counts due to thermal dark current. Previous studies have revealed that the DS1 is important in particular for the appropriate assessment of the hydrogen signal in the first single-shot spectra [8]. However, due to time and data constraints, the DS1 is usually not recorded when a targeted sample is analyzed. The blind target data therefore constitutes a valuable data set for the investigation of hydrogen and its variability in the dust and soils. Moreover, the distance to the target and the laser energy, two parameters which are known to have major influences on the LIBS data, are constant within this data set.

ChemCam sampled the first blind target on sol 318 of the mission. The present study includes data collected from this starting date up to sol 588, spanning nearly half a martian sidereal year. This window encompasses different martian seasons. Moreover, a sample group of more than 300 individual locations in the blind targets provides sufficient data for rigorous statistics – and the opportunity to investigate possible diurnal variation of hydrogen. ChemCam measurements of soils taken after sunset and before dawn are compared to the data for the blind targets, which were collected during the martian day. A carbon peak (from the CO₂ atmosphere) is also monitored because it slightly overlaps the H emission line at 657 nm.

The blind targets were divided into three groups, based on comparison of RMI pre- and post-LIBS close-ups per position as well as on shot-to-shot variability and typical H SBR trends (Fig. 1). The "rock" group is characterized by high H SBRs in the first single shot spectra, due to the dust cover, followed by a rapid decrease in abundance and low variability towards a low constant value (Fig. 1 left). This group also contains data for pebbles that appear as solid dust-covered targets due to the small sampling size of LIBS. The second group comprises fine-grained soils with high H SBRs and high shot-to-shot variability at a sin-

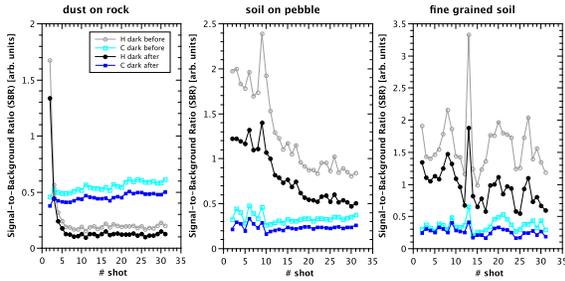


Figure 1: Typical depth trends for hydrogen and carbon signal-to-background ratio (SBRs) as observed on rocks, soil-pebble mixtures, and fine-grained soils. The data were processed with the appropriate DS1 and DS2, respectively.

gle spot (Fig. 1 right). Targets, such as a buried coarse grain or pebble, that did not fall into one of these two groups, were assigned to a third group (Fig. 1 middle).

The data shown in Fig. 1 were processed with both DS1 and DS2, respectively. DS1 should be used for data processing of the first 3-5 single shot spectra while the DS2 after 30 shots matches better the majority of the later single-shot spectra (ca. shot #5-#30) [8]. Thus, H SBRs of the first single-shot spectra, in particular of soils, are typically underestimated for standard data acquisition with DS2 only. By contrast, use of a DS1 may overestimate slightly the first shots H SBRs, as the very first laser shot can already create a significantly shadowed crater in the before brightly illuminated soil.

Results

For the dust, a mean H SBR of 1.74 ± 0.27 was obtained, which is a bit lower than the mean of the first shot H SBR in the soils with 1.83 ± 0.32 . As mentioned above, the soil H SBR of the first shot might be overestimated slightly while the value for the dust is not much affected, suggesting that both the dust on the rocks and the soil surface are similarly hydrated. For comparison, a mean H SBR of the shots 6 to 30 was calculated for the soil with the appropriate DS2. These soil mean values (1.34 ± 0.41) are typically smaller than the 1st shot H SBRs and comparable to the H SBR typical for mean soil spectra of 1.10 ± 0.35 presented in [3]. The latter value is reduced as it is obtained from a mean spectrum which also includes some data of pebbles and coarse grains and not from single shot analysis of fine-grained soils only, as was done in the

present study. The higher H SBR of the first shot spectra relative to the soil mean might indicate a higher hydration of the surface, although effects such as plasma confinement in the evolving crater and use of the DS2 could reduce the H SBRs of the soil slightly. Three measurements of a single position each on soils were conducted on sols 74, 316, and 544 before sunrise in the morning. These data are not affected by the use of a DS1 or DS2 and gave very similar first shot H SBRs of 1.30 ± 0.03 . A fourth soil measurement sampled 5 positions after sunset on sol 582, resulting in first-shot H SBRs of 1.68 ± 0.33 . These are in agreement with the H SBRs obtained from the dust during day and the probably slightly overestimated first-shot SBRs of H in the soils.

XRD analysis of soil samples at Rocknest revealed that the hydration of the fine soil particles seen by SAM and ChemCam in this sand shadow is associated with the presence of an amorphous component of 30 to 50 wt.% [5, 9, 10]. The similar H signal measured by ChemCam could indicate that this hydrated amorphous component is found in all the fine particles covering the surface of rocks and soils.

Over the time of the 270 sols where blind targets were sampled, no significant variation with sol or the local mean sol time (LMST) was observed, not in the total data of first-shot H SBRs of the blind targets, nor in the defined groups of dust on rock and soils.

Summary: The H SBRs of the first-shot spectra from dust on rocks and soils are very similar, indicating a similar level of hydration. The H SBR obtained from greater depth of the fine-grained soils however, is smaller than on the surface. This might indicate a more hydrated surficial material (dust). No diurnal variation of the hydrogen signal in ChemCam data nor variation following seasonal changes or due to a change in terrain were observed so far.

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