SUPERCAM RAMAN ONBOARD MARS 2020 ROVER: COMPARISON WITH LABORATORY RESULTS.

I. Torre-Fdez\textsuperscript{1}, K. Castro\textsuperscript{1}, O. Beysac\textsuperscript{2}, A. M. Ollila\textsuperscript{1}, J.M. Madariaga\textsuperscript{1}, G. Arana\textsuperscript{1}, S. Bernardi\textsuperscript{2}, P. Bernardi\textsuperscript{4}, P. Cais\textsuperscript{4}, S. Clegg\textsuperscript{3}, M. Egan\textsuperscript{6}, O. Forni\textsuperscript{7}, O. Gasnault\textsuperscript{7}, I. Gontijo\textsuperscript{8}, J.A. Manrique\textsuperscript{3}, S. Maurice\textsuperscript{6}, A. Misra\textsuperscript{2}, G. Montagnac\textsuperscript{10}, T. Nelson\textsuperscript{3}, R. Newell\textsuperscript{3}, P. Pillier\textsuperscript{7}, S. Robinson\textsuperscript{3}, F. Rull\textsuperscript{9}, S.K. Sharma\textsuperscript{6}, R.C. Wiens\textsuperscript{3}, P. Willis\textsuperscript{8} and the SuperCam Science team. \textsuperscript{1}Univ. of Basque Country, Bilbao, Spain (imanol.torre@ehu.eus), \textsuperscript{2}IMPMC, Paris, France, \textsuperscript{3}LANL, Los Alamos, USA, \textsuperscript{4}LESIA, Meudon, France, \textsuperscript{5}LAB Bordeaux, France \textsuperscript{6}Univ. of Valladolid, Spain, \textsuperscript{7}IRAP, Toulouse, France \textsuperscript{8}JPL, Pasadena, USA, \textsuperscript{9}Univ. of Hawaii, USA \textsuperscript{10}ENS Lyon, France.

Introduction: Raman spectroscopy is one of the analytical techniques that SuperCam will carry in the payload of the upcoming Mars2020 mission. The instrument will be able to perform Laser Induced Breakdown Spectroscopy (LIBS), time-resolved Raman (TRR), luminescence (TRLS) and visible-infrared (VISIR) spectrometries, as well as capturing sound with a microphone and doing remote microimages (RMI). Thanks to the variety of techniques SuperCam carries, it will be able to assess remotely the mineralogical and chemical composition of the Martian surface \cite{1}. During the calibration process, the validity of the results obtained with the instrument was checked. Here, we present the comparison between the Raman results obtained with SuperCam and the ones obtained of the same minerals and samples with a high-end bench-top commercial instrument. The main objective was to check that SuperCam provides similar results to the ones obtained with a commercial Raman that works with a spot size of ~1 µm and with a continuous laser.

Instrument description: SuperCam uses a Nd:YAG 1064 nm laser doubling its frequency to 532 nm for Raman analyses. It performs 4 ns pulses with 10 mJ/pulse energy at a 10 Hz repetition rate. The laser is collimated on the target, illuminating a surface of a few mm\textsuperscript{2} yielding an irradiance in the range 10\textsuperscript{8} to 5.10\textsuperscript{4} W.mm\textsuperscript{-2} on the target's surface. SuperCam’s telescope collects light within the laser footprint with a collection area ranging from ≈1.5 mm\textsuperscript{2} at 2 m to ≈5.2 mm\textsuperscript{2} at 7 m. The light collected for TRR is directed to a high-end bench-top commercial instrument. The main objective was to check that SuperCam provides similar results to the ones obtained with a commercial Raman that works with a spot size of ~1 µm and with a continuous laser.

Measurement parameters: SuperCam has been tested during several campaigns using various configurations (EQM: engineering qualification model, FM: flight model, BU: Body Unit, MU: Mast Unit). Here, we present some results from the tests carried out with the EQM-MU/FM-BU configuration in 2019 at LANL and the FM-MU/FM-BU final configuration in 2019, after its integration onto the rover at JPL. The Raman analyses were performed doing 100-200 shots, trying different combinations of addition (co-adds) on the CCD, and averaging single spectra collected separately on the CCD.

The measurements with the inVia were carried out using low intensity with the laser (less than 20 mW in the sample’s surface) and optimizing the number of accumulations to obtain the best Raman spectrum.

Reproducibility of SuperCam Raman: One of the parameters that was checked for the Raman results of SuperCam was the reproducibility of the spectra for the same mineral, testing the most probable wavenumber range of the expected mineral phases in Mars. This test was carried out with calcite, gypsum, apatite, quartz and talc, doing analyses during different days and in the same day. The aim was to check the variability of the spectra signals, which is an essential parameter in order to differentiate minerals of the same geological group for instance. In the Table 1, the average wavenumber position for the maximum of the main Raman signals for each mineral, their standard deviation ($\sigma$) for the different measurements and the RSD can be observed. As seen, no systematic trend was observed.

Table 1. Reproducibility information for the main peak positions of some minerals studied by SuperCam Raman.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>SuperCam average signal position (cm\textsuperscript{-1})</th>
<th>Standard Deviation ($\sigma$)</th>
<th>RSD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcite</td>
<td>1087</td>
<td>0.47</td>
<td>0.044</td>
</tr>
<tr>
<td>Gypsum</td>
<td>1007</td>
<td>0.091</td>
<td>0.0092</td>
</tr>
<tr>
<td>Apatite</td>
<td>956</td>
<td>1.6</td>
<td>0.16</td>
</tr>
<tr>
<td>Quartz</td>
<td>465</td>
<td>2.2</td>
<td>0.47</td>
</tr>
<tr>
<td>Talc</td>
<td>203</td>
<td>0.77</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Moreover, under cleanroom conditions, the results from the Raman spectra of SuperCam present almost no variation in the same day or between several days, regardless of the mineral group that is being studied. The instrument temperature will vary more on Mars, and so wavenumber reproduci-
bility will be re-checked after landing. Based on tests performed over temperature at LANL, wavelength could shift by up to ~0.08 nm between minimum and maximum spectrometer temperatures. The shift should be reproducible with temperature, which is also measured onboard, so we expect to retain stability to well under 1 cm⁻¹.

Raman peak stability should allow us to distinguish between similar spectra of the same mineral group. For instance, in Figure 1 the spectrum of dolomite (CaMg(CO₃)₂) and calcite (CaCO₃) can be observed. Even though these two carbonates have very similar characteristics and a very similar Raman spectrum, SuperCam is able to distinguish between them because their main signals have almost no variability (uncertainties are 2σ).

Comparison with a commercial instrument: After the integration of the flight model of SuperCam into the Mars2020 rover, a calcite slab was analyzed to check that the Raman spectrometer was working properly. This step is useful to assess the quality of the results of the instrument that is flying to Mars in comparison with the response of a commercial instrument on the same sample. Figures 2 and 3 show the Raman spectrum of the same slab analyzed with the FM-MU/FM-BU final configuration of SuperCam and the inVia Raman instrument (Renishaw, UK), respectively.

As it can be observed, the quality of the SuperCam Raman spectrum for the same sample is comparable to the one obtained with a bench-top instrument. In this case, the accuracy of the results falls inside the uncertainty of the instrument, thus, it can be affirmed that SuperCam is sensitive enough to detect and differentiate among different mineral phases, even from the same group of carbonate, sulfate, phosphate, etc. Other Raman and TRLS results from SuperCam can be found in [4], showing the aforementioned capability.

In addition, it has almost the same quality regarding signal-to-noise ratio, which is a very good parameter taking into account that SuperCam is a remote instrument and the inVia uses a confocal microscope to perform the analyses. Finally, the relative intensities of the areas below the peaks obtained are almost the same, 0.40:0.11:1 for the inVia and 0.44:0.11:1 for SuperCam, for the 282, 713 and 1087 cm⁻¹ peaks, respectively.

Conclusions: The Raman instrument of SuperCam performs very well regarding different quality parameters for Raman spectroscopy. This fact has been checked both doing a comparison with a commercial high-end bench-top Raman instrument and comparing SuperCam results within-day and between days. These quality tests have been performed with minerals of high interest for the Mars2020 mission, such as carbonates, which provide excellent Raman results.

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