Mars Imaging by the ChemCam Remote Microscopic Imager (RMI) Onboard Curiosity: The First Three Months. S. Le Mouélic[1], O. Gasnault[2], K.E. Herkenhoff[3], Y. Langevin[4], S. Maurice[2], N.T. Bridges[5], P. Pinet[2], N. Mangold[1], J.R. Johnson[5], R.C. Wiens[6], J.F. Bell III[7], A. Cousin[2], G. Dromart[8], and the MSL Science Team. [1]Laboratoire de Planétologie et Géodynamique, CNRS, Université de Nantes, France, [2]IRAP, Toulouse, France. [3]USGS, Flagstaff, AZ, USA. [4]IAS, Orsay, France. [5]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [6]Los Alamos National Laboratory, New Mexico, USA. [7]School of Earth & Space Exploration Arizona State University, USA. [8]Université de Lyon, France. [stephane.lemouelic(at)univ-nantes.fr]

Introduction: The ChemCam instrument onboard Curiosity rover is a package of a Laser-Induced Breakdown Spectrometer (LIBS) coupled to the Remote Micro-Imager (RMI) [1,2]. Its main objective is to remotely determine the elemental composition of soils and rocks situated at distances up to 7 meters from the rover, without contact. We focus here on the imaging capability of ChemCam using the RMI (see also [3] for the camera performances) and initial analysis of RMI data.

Detection of the laser spots: The objectives of the RMI are to provide geomorphologic context of the LIBS analyses, locate the laser pits, document the changes induced by the laser shots on the target, and study the martian rocks and soils at high resolution. It is also the main tool to check the focusing of the laser, which is directly related to the intrinsic quality of LIBS spectra. This is particularly important for targets displaying significant variations of depth within the scene, and for which the optimum focus distance might differ from one LIBS point to the other.

During the first three months of the surface mission, well defined holes have been generally observed on soils (Fig. 1), whereas the laser pits were sometimes hardly detectable on the most consolidated rocks. RMI coupled to the LIBS provides a way to investigate the rock hardness. The first images also demonstrate that the camera by itself adds a significant scientific value to the study of rocks by revealing their fine texture and morphology [4].

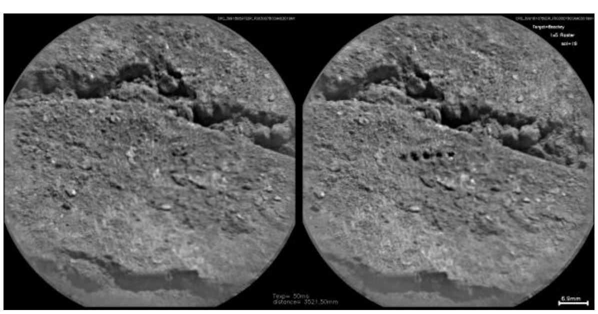

Figure 1. Example of ChemCam RMI images before (left) and after (right) a LIBS activity on a typical soil (target Beechey acquired sol 19, with illumination from upper right).

RMI mosaics : To characterize a target, an initial RMI image is generally acquired, followed by a series of laser shots (called a raster, with 30 laser shots in each individual point), and then a second image documenting the changes is acquired. By merging the pre- and post-LIBS images, a mosaic of the target can be built. The pre- and post-LIBS are also used to detect subtle laser pits between the overlapping part by differencing the two RMI images. Figure 2 shows examples of the Anton target in the rover wheel track on Sol 49.

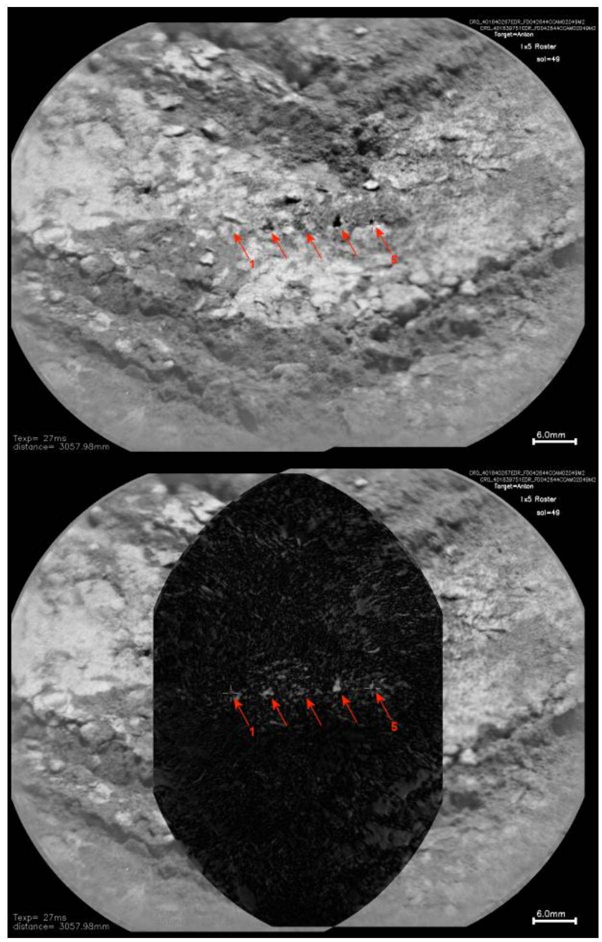

Figure 2. Examples of RMI derived products on Anton soil target. Top : mosaic of the pre- and post-LIBS images. The post-LIBS image is in the foreground. Bottom : pre- and post-LIBS images differenced to reveal the location of the five subtle laser holes (arrows) in the overlapping area.

Adding color to RMI images: The ChemCam RMI acquires 1024x1024-pixel black and white images, with a pixel angular size of 20 µrad. This pixel size is 3.7 times smaller than one of the Mastcam Right images, and can therefore be useful when high spatial resolution is needed. In the cases of targets which are observed simultaneously by the RMI and Mastcam, color information can be added to the RMI by using a pansharpening algorithm, which is commonly used in remote sensing. Merging the high spatial resolution RMI images with the color information of Mastcam images produces an integrated product which can be helpful in interpreting the diversity of the LIBS signatures in a given raster, as shown in figure 3 of Jake Matijevic rock [5]. True color images might be used to gauge the dust expulsion by the laser impacts on the targets. This process shall prove to be much more discriminative when enhanced false color images or Mastcam multispectral ratio composites are used.

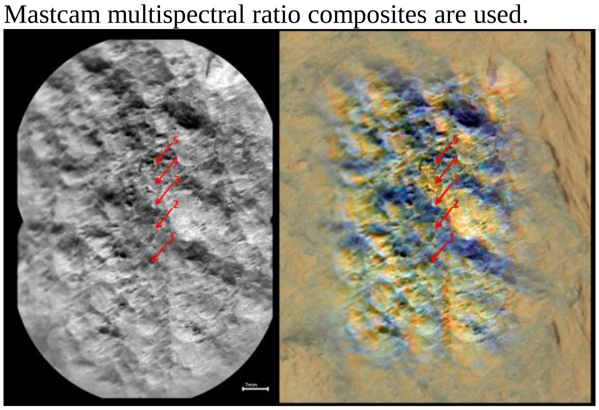

Figure 3. Left : Example of RMI mosaic taken on the rock "Jake Matijevic" (sol 45). Right: same RMI colorized with a stretched MastCam Right image. Arrows indicate the location of the five laser shots.

Retrieval of topographic information using the z-stack technique: We can also take advantage of the narrow depth of field of RMI images (about 1 cm at a distance of 2m [1]) to retrieve some distance information on scenes with subsequent volume variations. This can be achieved by evaluating the well-focused areas in a series of images of the same target taken at various focus distances [6]. During the first 90 sols, two targets were imaged using this technique, called z-stack, commonly used in lab microscopy : Pekanatui on Sol 33 and Zephyr on Sol 76. In addition to the retrieval of 3D information, the main goal of the z-stack technique is to provide a synthetic image that is sharp everywhere in the field of view. Figure 4 (bottom image) shows a 3D reconstruction performed on the rock called Zephyr, situated at a distance of 2.6m from ChemCam, and observed using a series of 9 images with focus planes separated by 9 mm, scanning the distance range between 2.61 and 2.68m. The examples shown in Figure 4 clearly validates this strategy.

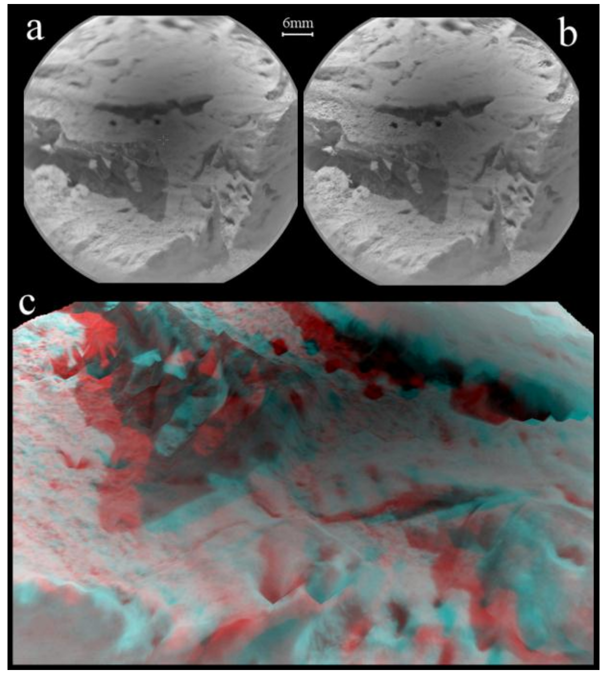

Figure 4. Example of z-stack on the target Zephyr, (a) single RMI image. (b) focus merged product obtained from a series of 9 images acquired with focus distances seperated by 9 mm.(c) anaglyph showing the 3D information (requires red-blue glasses).(b) and (c) were generated with the Heliconfocus software.

Conclusion and Perspectives : The RMI has the highest spatial resolution of the cameras on MSL's remote sensing mast, and is therefore very complementary to Curiosity's other imaging instruments in investigating remotely the fine texture of rocks and soils, in addition to its ability to identify the precise location of the ChemCam laser shots. Secondary byproducts including mosaics, images with added color, and topography of the targets, will complement the results of the elemental composition analysis performed by the LIBS, to converge toward an integrated understanding of the rocks and soil history at Gale crater.

Bibliography: [1] Maurice et al., Space Sci. Reviews, Vol 170, Issue 1-4, pp. 95-166, 2012. [2] Wiens et al., Space Science Reviews, Space Sci. Reviews, Vol 170, Issue 1-4, pp. 167-227, 2012. [3] Langevin et al., *LPSC XLIV, 2013*. [4] Bridges et al., *LPSC XLIV, 2013*. [5] Cousin et al. , LPSC XLIV, 2013. [6] Herkenhoff et al., JGR, 111, E02S04, 2006.