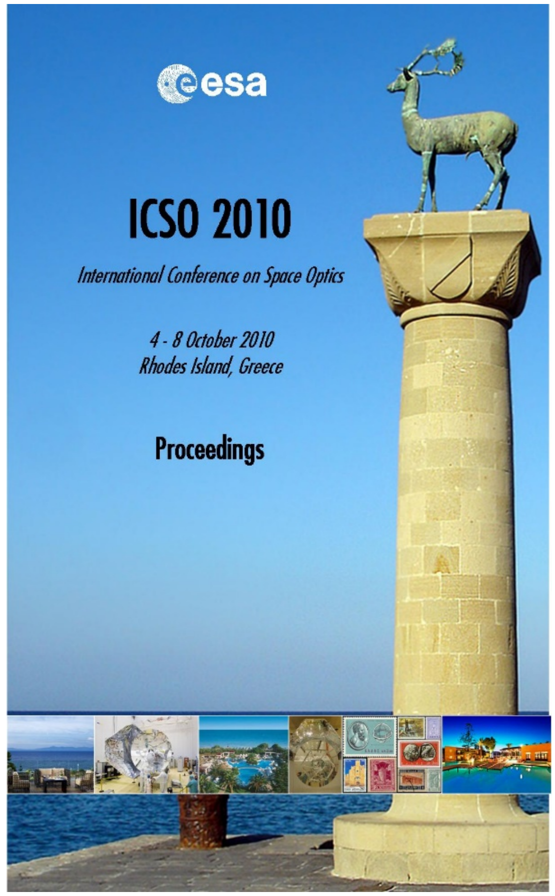
International Conference on Space Optics—ICSO 2010

Rhodes Island, Greece

4–8 October 2010

Edited by Errico Armandillo, Bruno Cugny, and Nikos Karafolas



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International Conference on Space Optics — ICSO 2010, edited by Errico Armandillo, Bruno Cugny,
Nikos Karafolas, Proc. of SPIE Vol. 10565, 105655O · © 2010 ESA and CNES
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2552567

DETERMINATION OF THE FIRST LEVEL IMAGE PROCESSING OF THE CHEMCAM RMI INSTRUMENT FOR THE MARS SCIENCE LABORATORY (MSL) ROVER.

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1. INTRODUCTION

ChemCam is an active remote sensing instrument to investigate details of the Martian geochemistry using the Laser Induced Breakdown Spectroscopy (LIBS) technique [1], and Remote Micro Imaging (RMI), to be flown on the Mars Science Laboratory (MSL) rover scheduled for launch in 2011.

The RMI camera, previously developed for Roseta mission, and provided by IAS, is a precise imager (78-105µrad for a field of view of 22mrad) and will be used as a microscope to see tiny details such as LIBS impacts, as well as the morphologic context of the LIBS analyses, on the targets, thanks to a larger view of the rocks. The RMI is part of the Mast Unit, delivered by CNES / CESR (France).

RMI pictures are marred with defects [2], some of them due to the camera technology, and others to the instrument optics. Among all these picture deteriorations, some are negligible, while others are penalizing. This work describes how we used data from experimentation on particular scene (USAF target, uniform lighting…) to build overall algorithms which have been tested on rock scenery pictures, and will be used by the science team to correct images taken on Mars.

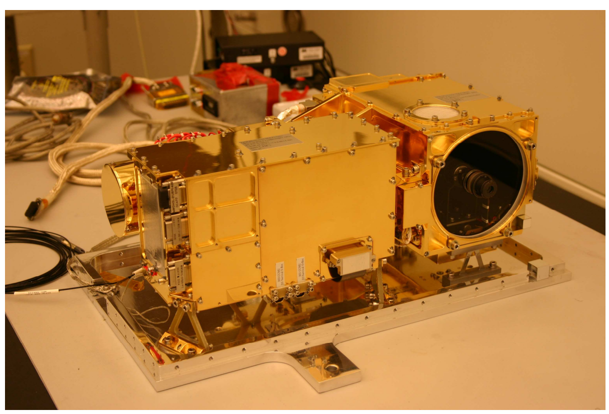

Fig. 1 : ChemCam Mast Unit

2. OPTICAL CONCEPT

Light from the scene enters the telescope and is focused to the CCD matrix thanks to a set of lenses and mirrors (fig.2). Two dichroïc dioptres have been used to separate the various optical paths. The Laser dichroïc reflects light around 1067 nm (LIBS laser beam), while other rays (visible and UV light emitted by the plasma) pass through it. The RMI dichroïc reflects only 20% of the visible radiation.

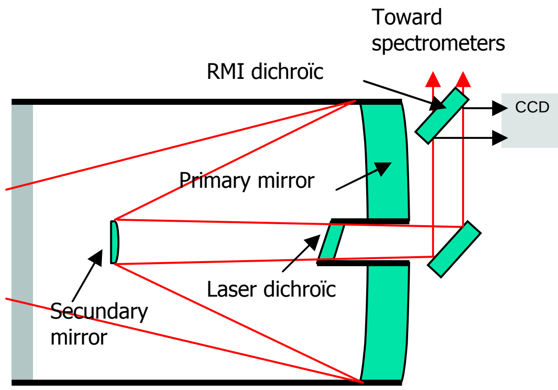

Fig 2 : light path in the telescope

3. IMAGE IDIOSYNCRASIES

Six main defects are studied on our system. For each of them, we explained the physical phenomenon, we quantified its impact on the total image and we determined the different parameters in function of which its appearance evolves. The CCD technology, and the particular frame transfer CCD used, creates a first kind of defects.

- Raw images present an offset called bias corresponding to a false zero of each pixels. It depends mostly on temperature.
- Obscurity current due to thermal signal increases pixels value. To isolate the optical flux, we must subtract this signal depending on temperature and integration time.
- A pixel answers a value proportional to the light intensity received on a particular range. Above a maximum value, we reach a non linear zone, and then saturation. Moreover, these characteristics depend on each pixel.
- The data transfer technology imposes a charges displacement on the matrix. As there is no shutter on the instrument, this displacement creates the smearing, white drag below luminous spots (fig.3).

The optical path followed by the beam in the instrument induces variations in the final picture.

- The transmittance of the series of mirrors and lenses crossed by light rays evolves depending on the distance with the centre of the field of view. So a flat-field does not match with a constant value on the matrix : the image appearance depends strongly on the distance of the target. This succession of lenses and mirrors creates also distortion.
- An intrusive reflection (called the ghost) on the last dioptre before the CCD duplicates the scene on the final image, and must be deleted not to hide the net area.

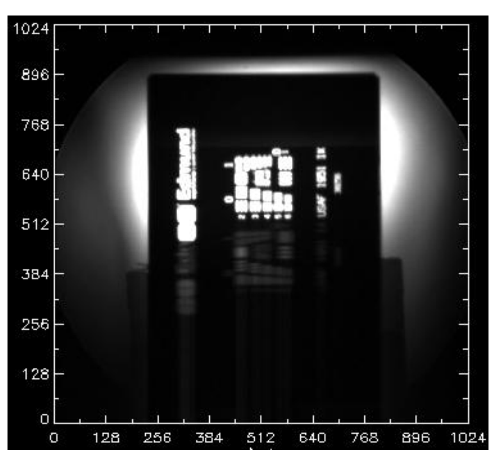

Fig. 3 : Picture of the USAF target (light intensity multiplied by 5 to show ghost and smearing)

4. DATA PROCESSING

Some of the defects described do not need any correction. The distortion has been evaluated at less than 0.2%, the CCD already has an anti-blooming, the direct light received by the CCD can not be evaluated, and thus, can not be corrected on in-flight pictures.
To correct some other defects, we just need information contained in the picture. The smearing and the ghost correspond to some light received by the sensor, at least temporarily and the pixel response is related to the intensity of another point in the matrix. These information, added to picture information such as integration time, is enough to calculate the intrusive response pixel by pixel. The correction depends only on the pixel response of the picture itself, and a simple algorithm allows to correct it.
To compensate the last defects (dark and flat), a data bank is required. Indeed, they depend either on the distance between the target and the instrument, or on temperature and integration time. Anyway, as only a finite number of points is available from measurements, we have to interpolate these points to be able, once on flight, to rebuild necessary darks and flats whatever the distance and temperature are.
Four deformations will be mainly corrected in our images. But the processing order is really important : for instance, ghost creates smearing, so we must remove smearing before ghost. In fact, processing must be applied in the exact reverse order from the creation of the defects in the picture taking (fig.4).

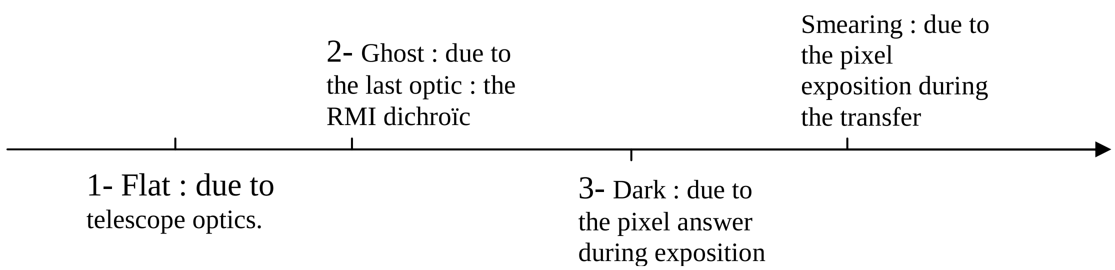

Fig 4 : Order of apparition of the defects in the image creation process

The Ghost and the Flat are specific to our instrument, while the others are generic. The four of them will be developed in the poster, but only Ghost and Flat are described in this abstract.

A. Ghost
At the rear of the telescope, the incident light is splitted by a beamsplitter: a fraction of light goes toward the spectrometers, and another arrives on the RMI CCD (fig.5). Despite the optical surface coating of the dioptre, a fragment of the light is reflected by the second face of the dioptre, and creates an intrusive reflection called “ghost”. We worked on particular pictures to determine the position of this ghost, and the ratio between its intensity and the the one of the pixel located 190 lines above. These pictures are RMI of a target called ‘USAF’ and allowed us to build the algorithms necessary to remove the ghost.

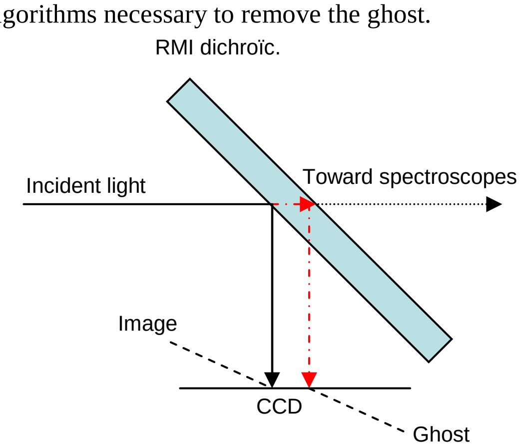

Fig. 5 : light rays on the RMI dichroïc

B. Flat

The flat is the RMI picture of an uniform lighting (fig.6). The rims of the picture received a lower light intensity than its centre. It characterizes the optical system transmission on all the field of view. The processing aims to raise the pixel values on the rims so that the average by zone is a constant on all the matrix. Construction of these flat-field pictures is experimental. With an integrating sphere, an uniform light source, we took pictures for several distances. After basic correction (removal of the thermal and electronic noises, correction of smearing and ghost), we compared the different pictures and showed that flat-fields were really dependent on distance. But once on flight, we will not be able to take anymore flat-field images, and, to process a picture, we will need the flat-field image at the same distance : we must find a solution to build a Flat from a databank filled before launching. Finally, we showed that processing a picture by the linear interpolation between the two closest flat-fields in the database gave much better results than processing it by the closest flat-field image. The standard deviation of the residual error after applying this method (interpolation) was 0.5% compared to 2% with the first processing (closest flat), and 40% before processing.

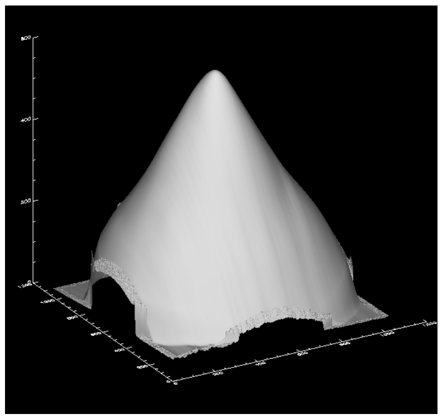

Fig. 6 : Flat in three dimensions

5. CONCLUSION

The corrections to apply to the RMI pictures are determined : working on particular targets [3], such as the USAF target, we wrote the algorithms necessary to remove smearing and ghost. Creating data bases from dark pictures or uniform lighting images, we computed parameters to build the correction whatever the conditions will be on Mars.

We are now processing pictures of rocks to validate our corrections. To go further, we will have to improve the flat-field processing of the bottom of the picture. Then other idiosyncrasies of the CCD could be corrected, such as differential linearity between pixels, or loss of linearity above 750 counts and before saturation.

Finally, these algorithms will be delivered to the science team to be applied on Mars RMI pictures for a first level image correction.

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