CORRECTION OF STRAY LIGHT IN CHEMCAM REMOTE MICRO-IMAGER LONG DISTANCE IMAGES. S. Le Mouelic\textsuperscript{1}, O. Gasnault\textsuperscript{2}, K.E. Herkenhoff\textsuperscript{3}, H.E. Newsom\textsuperscript{4}, Z. Gallegos\textsuperscript{4}, W. Rapin\textsuperscript{5}, R. Anderson\textsuperscript{6}, L. Le Deit\textsuperscript{7}, N. Mangold\textsuperscript{8}, G. Dromart\textsuperscript{8}, J.R. Johnson\textsuperscript{9}, S. Maurice\textsuperscript{9}, R.C. Wiens\textsuperscript{10}. \textsuperscript{1}Laboratoire de Planétologie et Géodynamique, CNRS UMR6112, Université de Nantes, France, \textsuperscript{2}IRAP, Toulouse, France. \textsuperscript{3}USGS, Astrogeology Science Center, Flagstaff, AZ, USA. \textsuperscript{4}University of New Mexico, Albuquerque, USA. \textsuperscript{5}Caltech, Pasadena, USA. \textsuperscript{6}LGL TPE, Univ. Lyon, France, \textsuperscript{7}JHU, APL, Laurel, MD, USA. \textsuperscript{8}LANL, New Mexico, USA. [stephane.lemouelic(at)univ-nantes.fr]

Introduction: The ChemCam instrument onboard the MSL “Curiosity” rover is a package of a Laser-Induced Breakdown Spectrometer (LIBS) coupled to the Remote Micro-Imager (RMI) \cite{1,2,3}. Its objective is to remotely determine the elemental composition of soils and rocks situated at distances up to 7 meters from the rover. The primary objectives of the RMI, which has a pixel angular size of 19.6 µrad/pixel on a 1024x1024 grayscale detector, are to provide geomorphologic context for the LIBS analyses, locate the laser pits, document the changes induced by the laser shots on the target, and remotely study the Martian rocks and soils at high resolution \cite[e.g. 4, 5, 6,\ldots]{7}. While it was not originally designed for this purpose, RMI can also occasionally serve as a powerful long distance imaging tool with improved performances thanks to an autofocus algorithm based on an onboard analysis of a Laplacian score computed on the RMI images \cite{7}.

In a few occasions, we noticed that a spurious bright halo was observed on long distance images calibrated using the standard pipeline. We discuss the origin of this problem and propose a preliminary solution.

![Figure 1](image1.png)

**Figure 1.** Left: ChemCam RMI CR0_509621201 (sequence CCAM03262) affected by a bright surrounding halo, most probably due to scattered light from the sky entering the telescope. Right: image CR0_511399990 (sequence CCAM02283) taken on lower layers of Mount Sharp, and not affected by the bright halo.

Observations at long distance with RMI: The RMI angular pixel size corresponds to \sim 20 cm at 10 km. Even with a conservative estimate of a line spread of 4-5 pixels \cite{8}, RMI provides long distance views which are very complementary to HiRISE orbital images in the 5-15 km range. The first target imaged at infinity with RMI was Ameto (Sol 327, pointing at \sim 9 km toward the base of the Greenheugh pediment). Since the Ameto imaging test, several distant observations have been made by pointing either toward the Gale crater rim in the Peace Vallis direction \cite{9}, or toward Mount Sharp lower and upper strata \cite{10, 11, 12}. When observing in the Peace Vallis direction, a systematic bright halo appears to affect almost all RMI images using standard processing (Fig. 1 left). This effect has also sometimes been observed when pointing toward Mount Sharp, but it is much less systematic (Fig 1 right). Simulations seem to indicate that this stray light likely comes mainly from 3 to 4.5° angles away from the telescope boresight. Scattered light coming from the sky or from bright areas can thus contribute to this effect, depending on the rover and camera orientations.

Empirical correction of the scattered light: The Peace Vallis imaging campaign resulted in the acquisition of more than 250 images taken with approximately the same observing geometry, between Sol 1237 and 2012. Thanks to this homogeneity, we have been able to extract the bright halo pattern from this consistent set of images by computing a median filter on the stack of these 250 single observations. The median filter performed on a pixel by pixel basis proved to be very effective in removing the bright and dark features in each scene, leaving mostly the globally fixed low frequency bright halo pattern (Fig. 2).

![Figure 2](image2.png)

**Figure 2.** Retrieval of the bright halo pattern using a median stacking of 250 RMI images of the Peace Vallis area (upper images). The image on the lower right has been corrected using the retrieved bright halo pattern (bottom left).
Correction of the mosaics: Once retrieved, the bright halo pattern can be used as a secondary empirical flat field correction to remove this spurious effect on the images. An example is given in Fig.3, which compares mosaics computed before (Fig. 3b) and after (Fig. 3c) this additional processing step. The homogeneity of the mosaic is improved by the correction, allowing the generation of completely artefact-free images (Fig. 3c, d).

Even though this strategy proved to be useful in the case of Peace Vallis observations, we have not identified the key parameter controlling the strength of the bright halo so far, which prevents the systematic implementation of this new correction in the official calibration pipeline. It will therefore rather be applied on a case by case basis.

Conclusion and future work
Imaging at long distance with Chemcam’s RMI provides the ability to study the detailed structure of Gale crater walls, or the fine-scale nature of the strata constituting Mount Sharp layers. It is also useful as a reconnaissance tool to investigate key locations of the forthcoming Curiosity traverse, or to look for temporal changes on Mount Sharp steep slopes [10]. In addition to radiometric improvements, additional tests are currently being made to evaluate the possibility of gaining some resolving power using either super-resolution or deconvolution techniques on single images. The super-resolution requires a set of 5 to 10 perfectly focused images, with a subpixel movement between each single acquisition.


Figure 3: Example of the radiometric correction of RMI mosaics acquired in the Peace Vallis direction (sequence CCAM03262 acquired from a distance of 24 km). (a) Left Mastcam mosaic acquired on Sol 1163 showing the context. (b) RMI mosaic from the standard calibration pipeline. (c) RMI mosaic after the new bright halo correction. (d) zoom on the corrected mosaic illustrating the resolving power of RMI.