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Stéphane Le Mouélic, Olivier Gasnault, Paolo Pilleri, Gwénaél Caravaca, Nicolas Mangold, Sylvestre Maurice, Kenneth Herkenhoff, Travis Gabriel, Roger C. Wiens, Horton E. Newsom, et al.

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## EMPIRICAL CORRECTION OF BRIGHT HALOS IN CHEMCAM AND SUPERCAM RMI LONG DISTANCE MOSAICS.

S. Le Mouélic<sup>1</sup>, O. Gasnault<sup>2</sup>, P. Pilleri<sup>2</sup>, G. Caravaca<sup>2</sup>, N. Mangold<sup>1</sup>, S. Maurice<sup>2</sup>, K. E. Herkenhoff<sup>3</sup>, T. S. J. Gabriel<sup>3</sup>, R.C. Wiens<sup>4</sup>, H. Newsom<sup>5</sup>, Z. Gallegos<sup>5</sup>, T. H. McConnochie<sup>6</sup>. <sup>1</sup>LPG, CNRS UMR6112, Nantes Université, France. <sup>2</sup>IRAP, UMR 5277 CNRS, UPS, CNES, Toulouse, France. <sup>3</sup>USGS, Flagstaff, AZ, USA. <sup>4</sup>Purdue, USA. <sup>5</sup>Univ. of New Mexico, Albuquerque, USA

**Introduction:** The ChemCam and SuperCam instruments onboard the Curiosity and Perseverance Martian rovers provide high-resolution imaging capabilities thanks to their Remote Microscopic Imager (RMI) cameras [1, 2, 3, 4]. RMI images are critical to document the spectroscopic analyses (LIBS for ChemCam and LIBS, Raman and passive infrared for SuperCam). They also provide a powerful tool to investigate the detailed texture and morphology of soils and rocks, and to perform geologic investigations at a long distance in Gale and Jezero craters, extending the scientific reach of rover assets.

In both cases, the standard calibration pipeline of RMI images provides accurate corrections of most of the observations. In a few cases, in very specific observing geometries, we sometimes observe a more or less pronounced bright halo at the edges of the images, which may come from stray light. This effect is currently not fully accounted for in the standard calibration pipeline of the two instruments. We here discuss some post-processing imaging tests aimed at evaluating this residual halo effect and decreasing its contribution in order to homogenize the mosaics.

**Description of the problem:** The RMI uses a compact Schmidt-Cassegrain telescope, with a fixed primary mirror and a movable secondary mirror, to acquire black and white (ChemCam) and color (SuperCam) images [1,2].

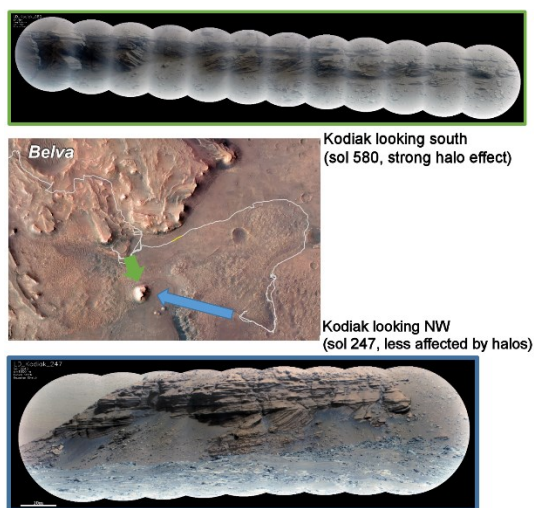


Fig. 1: Dependence of the bright halos with the viewing angle in SuperCam RMI long distance observations of the Kodiak Butte. Images acquired looking South (sol 580) are much more affected by bright halos than images taken looking North-West (sol 247).

This optical design was optimized for laser-induced spectroscopy more than for imagery, where only a small fraction of the light is used [1,2].

We observed that in specific observing configurations, both RMI imagers can show an increase of brightness at the edges of each image frame, even after their standard radiometric calibration [4, 5]. This effect is more pronounced in long distance images (for which the Remote Sensing Mast is pointing at higher elevations compared to images acquired in the nearby workspace), and seems to appear only when observing in specific directions. This is illustrated for example in Fig. 1 for SuperCam long distance observations of the Kodiak Butte. Fig. 2 shows the same phenomenon on ChemCam when observing the crater rim. We interpret these observations as a possible contribution of stray light from the sky and/or the sun entering the telescope and reaching the detector. This bright halo effect is also observed in a few occasions in close range observations acquired against the light direction.

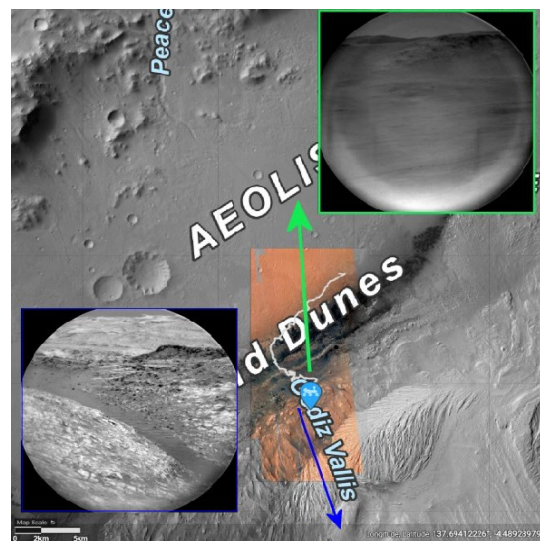


Fig. 2: ChemCam RMI observations with and without a bright halo. The halo appears in images pointing North and is almost absent in images pointing South (images CR0\_749305992PRC and CR0\_748417862PRC taken sols 3962 and 3953), suggesting a dependence with the viewing angle and illuminating conditions.

**Test of an empirical correction:** We tested a supplementary post-processing step applied after the standard calibration pipeline to account for a possible

additional stray light contribution. In this empirical approach, we automatically search for the value of a constant  $k$  which minimizes, for each color channel, the standard deviation of the quantity “(image -  $k$ )/sky”, where “image” is the image derived from the actual calibration pipeline and “sky” is a typical sky image also derived from the pipeline. Fig. 3 illustrates the computation of the minimum in the case of a SuperCam RMI image “SCAM\_0418\_0704036807\_229”. This empirical approach can be applied both for ChemCam and SuperCam.

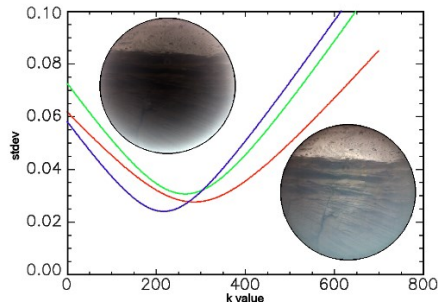


Fig. 3: Example of minimization of a residual component on SuperCam RMI image SCAM\_0418\_0704036807\_229, acquired on sol 418 in challenging lighting conditions. The insets show images before (upper left) and after (bottom right) the empirical correction revealing geologic textures.

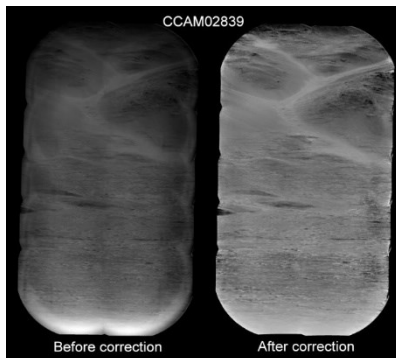


Fig. 4: Illustration on ChemCam RMI long distance observations of the Gale crater rim.

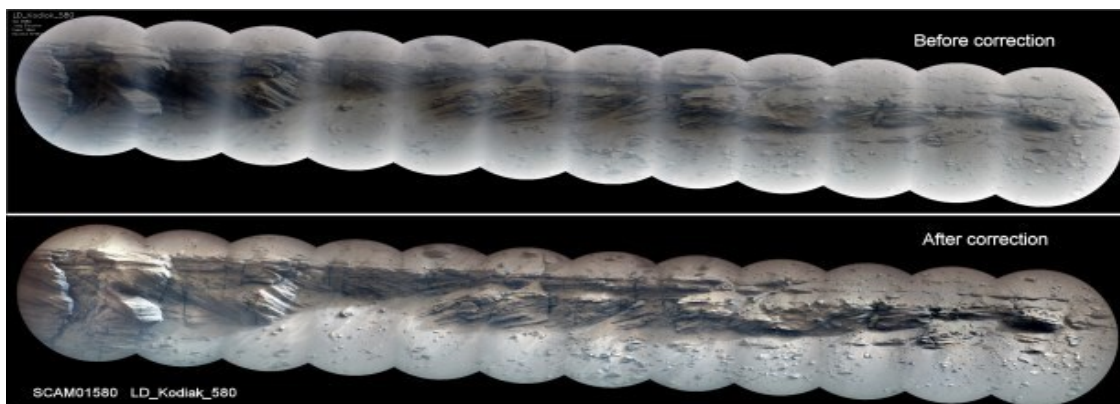


Fig. 5: Illustration on one of the Kodiak worst-case (against the light) illuminating conditions.

**Result on RMI mosaics:** Fig. 4 shows an example observation acquired with ChemCam on the Gale crater northern rim, therefore at a quite long distance (up to 30 km from the rover) through the scattering atmosphere and consequently with a low (useful) signal to noise (and stray light) ratio. The mosaic after the empirical correction of the halos (Fig. 4 right) has fewer artifacts.

Fig. 5 illustrates the result in the case of a SuperCam RMI observation of the Kodiak butte (sequence scam01580) also taken in challenging lighting conditions. The empirical correction of the halo applied on each image produces a more homogeneous mosaic in these examples.

**Conclusion and Future Work:** We have carried out several tests to decrease the influence of bright halos affecting a small subset of ChemCam and SuperCam RMI images. Empirical post-processing approaches generally succeed in correcting most of the bright halo effects, but the process cannot be applied blindly to the whole image collection yet since it is adjusted on a case-by-case basis. This method provides an interim solution for improving the aspect of mosaics until a more accurate, unsupervised technique is developed. The exact origin and quantification of this bright halo effect is still under investigation. Other contributions linked to the flat field characterization might also play a role in residual defects. Additional tests using the correlation with possible stray light detected in passive spectra and numerical simulations could be carried out in the future to disentangle the various parameters at the origin of this effect and possibly develop a more physics-based correction.

**References:** [1] Maurice et al., Space Sci. Rev. 170, 95-166, 2012. [2] Maurice et al., Space Sci. Rev. 217, 3, 2021. [3] Le Mouélic et al., Icarus 249, 93-107, 2015. [4] Gasnault et al., 52<sup>nd</sup> LPSC, LPI Contrib. No. 2548, id.2248, 2021. [5] Gasnault et al., 23<sup>rd</sup> EGU, 10.5194/egusphere-egu21-16461, 2021.