

CHEMCAM PASSIVE REFLECTANCE SPECTROSCOPY AT BRADBURY LANDING, MARS. J.R. Johnson¹, R. Wiens², S. Maurice³, S. Bender², L. DeFlores⁴, D. Blaney⁴, O. Gasnault³, E. Cloutis⁵, J. Bell⁶, M. Rice⁹, A. Fraeman¹¹, S. Le Mouélic⁷, T. McConnochie⁸, B. Ehlmann⁹, R. Leveille¹⁰, P. Pinet³, and the MSL Science Team, ¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, jeffrey.r.johnson@jhuapl.edu, ²Los Alamos National Lab, ³Research Institute in Astrophysics and Planetology, ⁴Jet Propulsion Laboratory/Caltech, ⁵University of Winnipeg, ⁶Arizona State University, ⁷Le Laboratoire de Planétologie et Géodynamique de Nantes, ⁸Univ. of Maryland, ⁹California Institute of Technology, ¹⁰Canadian Space Agency, ¹¹Washington Univ. in St. Louis.

Introduction: The Laser-Induced Breakdown Spectrometer (LIBS) portion of the ChemCam instrument uses three dispersive spectrometers to cover the ultraviolet (UV; 240-342 nm), visible (VIS; 382-469 nm) and visible/near-infrared (VNIR; 474-906 nm) spectral regions at high spectral (< 0.5 nm) and spatial (0.65 mrad) resolution. In active LIBS mode, light emitted from a laser-generated plasma is dispersed onto these spectrometers and used to detect elemental emission lines [1]. During instrument development it was understood that the ChemCam spectrometers exhibited sufficient sensitivity to allow collection of potentially useful surface spectral reflectance in passive mode. However, the spectrometers were not radiometrically calibrated for this purpose. Nonetheless, observations of well-characterized Mastcam and ChemCam calibration targets on the Curiosity rover provided the opportunity to test the passive spectral capability of ChemCam on Mars. Preliminary results demonstrate that relative reflectance spectra of these targets and surface materials are consistent with preliminary Mastcam spectra, Mars orbital spectra, and lab analyses of calibration targets and Mars analog soils.

Data and Methods. Typical ChemCam LIBS observations include 3 msec-exposure “dark” spectra (acquired with the LIBS laser off) used to remove the background signal from the LIBS measurement. Although such short exposure times provide useful signal for VNIR detector passive reflectance measurements, better optimization resulted from longer exposure times (30, 400, and 5000 msec for the VNIR, VIS, and UV spectrometers, respectively) and averaging of multiple (5-30) spectra. Such observations of surface targets were paired with measurements made at similar times of day and at identical exposure times (to minimize variations from dark current) of the ChemCam calibration Target #11 (TiO₂-based coating that exhibits ~95% flat reflectance in the ~400-900 nm region [1]) and/or the well-characterized Mastcam calibration target [2]. Raw data were converted to radiance using the instrument response function, the background offsets in each detector, the target distance and telescope aperture. By dividing the radiance spectrum for a given exposure by its companion radiance spectrum of

a calibration target, relative radiance spectra were produced for each exposure time. A combined spectrum was obtained by extracting the relevant data from each spectrometer region. Multiplying by the known laboratory reflectance of the appropriate calibration target allowed creation of a relative reflectance spectrum. Current work concentrates on the 400-840 nm region because the calibration targets exhibit near-zero UV reflectance, and the VNIR detector responsivities past ~840 nm and VIS below ~400 nm are relatively low.

Results. **Figure 1** shows Remote Micro-Imager (RMI) images of the white ring and green color chip on the Mastcam calibration target and the Target #11 location on the ChemCam calibration target holder. **Figure 2** shows relative reflectance ChemCam passive spectra of calibration targets #6 and #9 compared to their laboratory spectra (cf. Fig. 1) [3]. Also shown are spectra of the Mastcam calibration target green chip and white ring compared to their lab spectra. Spectra for the green chip are presented using both Target #11 and the Mastcam white ring for calibration. All spectra mimic their lab counterparts extremely well in spectral shape and overall reflectance values with the exception of the white ring. This is likely due to dust contamination on the white ring (visible in the RMI image), which causes greater reflectance longward of 500 nm compared to the lab spectrum [4]. By comparison, the region observed on the green color chip is nearly dust-free owing to the embedded sweep magnet [2]. Dust contamination of the ChemCam calibration targets is minimized by their ~45° tilt to the rover deck. **Figure 3** compares ChemCam passive spectra from a dark soil observed in a rover track on Sol 49 (“Anton”) to lab spectra of the Mars analog soil JSC-1, a palagonitic Hawaiian soil, preliminary Mastcam spectra of the same soil, and typical “bright” and “dark” visible detector spectra from the OMEGA instrument on Mars Express [5]. The similarity of these spectra provides additional confidence regarding the first-order calibration of the ChemCam and Mastcam reflectance spectra. The spectral similarity to palagonitic soils is consistent with the results from the ChemMin instrument for nearby soils that demonstrated similar mineralogy to Hawaiian palagonitic soils [7].

Future work. Ongoing work with ChemCam passive spectra will include efforts to utilize the UV spectral range (sensitive to iron content), investigate photometric effects of illumination variations on the calibration targets, dust mitigation efforts using established two-layer models [e.g., 2], and use of exoatmospheric solar irradiance as an independent means to calibrate the surface radiance spectra. As Curiosity traverses toward Mt. Sharp, passive spectra will be used as an additional tool to remotely track variations in surface chemistry and mineralogy, particularly for iron-bearing sulfate, oxide, and clay minerals.

References: [1] Wiens, R. et al., The ChemCam Instrument Suite on the Mars Science Laboratory (MSL) Rover: Body Unit and Combined System Performance, Space Sci Rev., in press, 2012; Wiens, R. et al., this conference; Maurice, S., et al., this conference; [2] Bell, J.F. III, Kinch et al., et al. this conference #1061; [3] Vaniman, D. et al., Space Sci Rev., DOI 10.1007/s11214-012-9886-0, 2012; Fabre, C. et al., this conference; [4] Johnson, J., and W. Grundy, GRL, 28, 2101-2104, 2001; [5] Ody, A., et al., JGR, 117, doi:10.1029/2012JE004117; [6] Cloutis, E., et al., Icarus, 197, 321-347, 2008; [7] Bish et al.; Blake et al.; Morris et al.; Morrison et al., this conference.

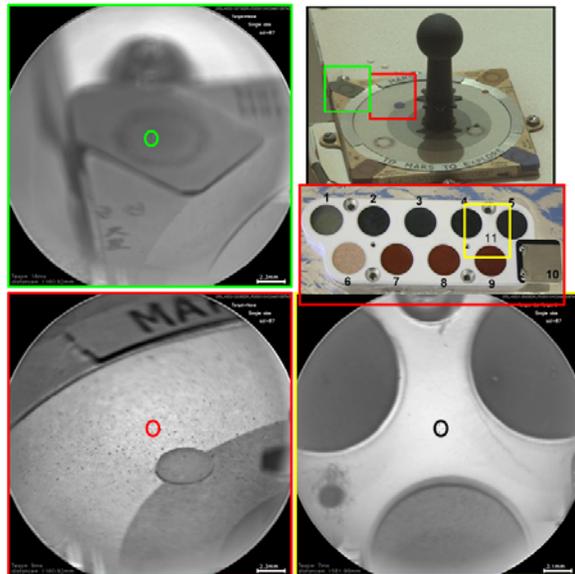


Figure 1. Remote Micro-Imager (RMI) images (~25 mm wide) from Sol 87 of the white ring and green chip on the Mastcam calibration target, and the “Target 11” location on the ChemCam calibration target holder. Circles represent 0.65 mrad field of view of passive ChemCam spectra (~1 mm). Mastcam M34 (left-eye) context image (Sol 13) shows RMI locations on the Mastcam calibration target (8 cm square) [2]. Laboratory image of the ChemCam calibration target (~16 cm wide) with numbered targets [3].

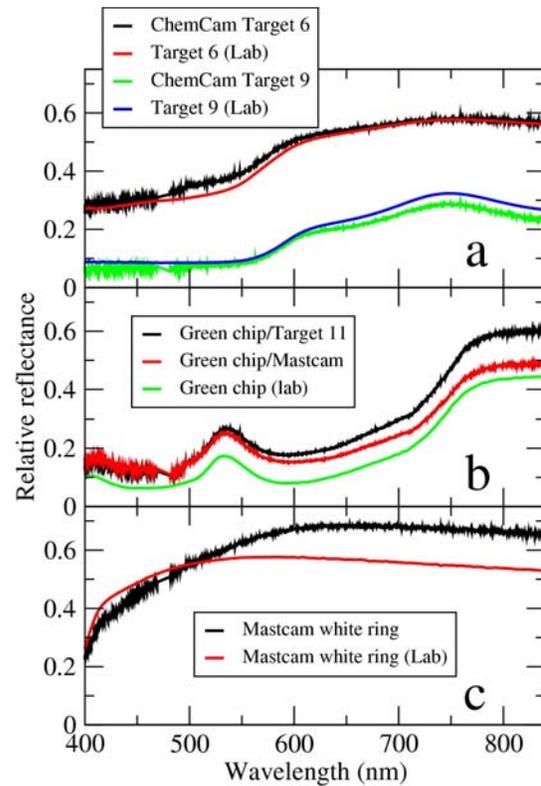


Figure 2. ChemCam passive relative reflectance and laboratory spectra of (a) representative ChemCam calibration targets #6 and #9 (cf. Fig. 1) acquired on Sol 33; Mastcam calibration target (b) green color chip (calibrated using both ChemCam Target #11 and the Mastcam white ring); and (c) Mastcam white ring.

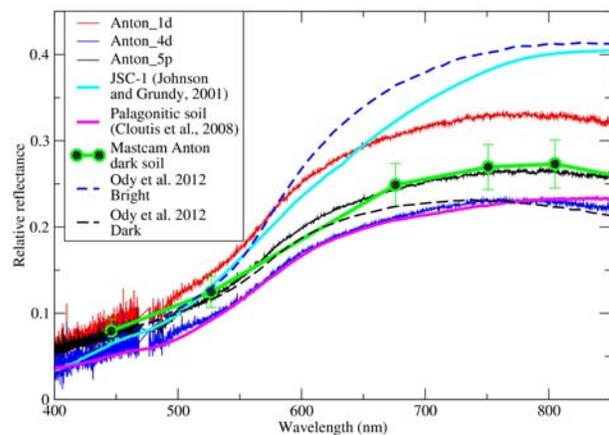


Figure 3. ChemCam passive relative reflectance spectra of Anton (rover track soil, Sol 49) compared to lab spectra of JSC-1 analog soil (wet-sieved <45 mm; [4]), palagonitic soil (dry-sieved <45 mm; [6]); preliminary Mastcam spectra of soil in the Anton track [2], and typical “bright” and “dark” spectra from OMEGA [5]. Anton_1d and Anton_4d are 3 msec exposures, whereas Anton_5p is combined from 30 and 400 msec exposures.