

AN ARCHIVE OF MARS SCIENCE LABORATORY CHEMCAM PASSIVE VISIBLE/NEAR-INFRARED SURFACE SPECTRA. C. O'Shea¹, J.R. Johnson¹, A.A. Fraeman², M. Lemmon³, ¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, Colleen.OShea@jhuapl.edu, jeffrey.r.johnson@jhuapl.edu, ²Jet Propulsion Laboratory, ³Space Science Institute.

Introduction: We announce the impending release of a Planetary Data System (PDS) archive of Mars Science Laboratory (MSL) Chemistry and Camera (ChemCam) passive radiance (240-905 nm) and relative reflectance spectra (400-840 nm) from ~23,800 surface observations acquired through Sol 2075 (June, 2018) by the Curiosity rover in Gale Crater. The data were calibrated using the methods of [1] through new Python-based calibration software that will be made available on the NASA GitHub site concurrently with the PDS archive release. Also included in the archive will be a table listing each passive observation along with metadata useful for future data mining.

Background. For every laser-induced breakdown spectroscopy (LIBS) point measurement acquired by ChemCam with its laser, a standard 3 msec exposure passive ("dark") measurement was acquired without the laser for background subtraction purposes. As shown by [1] these "dark" measurements were of sufficient quality to be used as passive radiance spectra when acquired on sunlit surfaces. Longer exposure ("dedicated") measurements also were acquired for specific targets of interest to increase the signal to noise ratio (SNR). Through Sol 2075 ChemCam acquired ~23,800 passive spectra of the surface, predominantly mm-scale measurements on rocks (~75%) and soils (15%), but also on calibration targets (9%), and >cm-scale long-distance observations (>500m; 1%). Data were most often acquired as rasters of 5 or more locations, and Remote Micro-Imager (RMI) images of the targeted area provided context and precise positions of the raster point locations, particularly when paired with Mastcam color images (**Figure 1**).

Calibration Methods. We used existing "passive" (PSV) observations from the PDS ChemCam archive (doi: 10.17189/1519485), and calibrated the data to radiance ($W/m^2/sr/\mu m$) for each of the three ChemCam spectrometers (UV (240-342 nm), VIO (382-469 nm), VNIR (474-905 nm)) [1]. The radiance spectra were then ratioed to observations of the ChemCam calibration Target #11 (the white painted calibration target holder) acquired on Sol 76, as described in detail by [1]. Owing to spectrometer response, reflectance data calibrated in this manner are intended for use only in the 400 nm to 840 nm region (with a small gap between the VIO and VNIR spectrometer regions). Data were calibrated to radiance and relative reflectance using the software described in the next section. **Figure 2** provides representative ChemCam passive spectra acquired of Murray formation bedrock in Gale Crater.

Calibration Software. As part of this effort, we created Python-based software to calibrate PSV files archived in the PDS. The ChemCam Passive Reflectance Observations Spectral Calibration Tool (*CCAM_PROSPECT*) allows for batch or interactive selection and processing of raw PDS PSV data files. Default settings replicate those described in the previous section. However, users may choose the radiance file of a preferred Target #11 spectrum (or use a different radiance spectrum altogether) should they not wish to use the default spectrum from Sol 76. This may be especially useful for calibration of data from later PDS releases that were acquired during high atmospheric dust opacity conditions (such as the 2018 dust storm).

Calibration routines can be invoked through either command-line or graphical user interfaces (GUI). Standard display and plotting options are available for users to visualize the relative reflectance spectra (**Figure 3**). A *User Guide* is available that describes the installation procedures for MacOS, Linux, and Windows platforms for Python 3.6 distributions (or higher). Descriptions and examples are provided for the command line and GUI interface options, along with a troubleshooting guide. Output files are PDS4-compliant, with .xml label files to support two-column ASCII .tab data files, where the first column is the wavelength (in nanometers) and the second column is either the radiance value or relative reflectance.

Metadata. An important component of the archive is ancillary information (metadata) collected for each spectrum. In addition to target name, filename, sequence identifier, target distance, exposure time, and observation time (in both Local Mean and Local True Solar Time), each raster location was categorized according to the type of target(s) sampled. We used these classes of target types: Sand, Soil, Bedrock, Float rock, Meteorite (Fe-Ni), Vein, Other Diagenetic features, Long distance, Drill tailings, Drill hole, Calibration target (including identification number [1]). These determinations were made through assessment of corresponding RMI mosaics and associated Mastcam images of the scene. RMI images were used to identify raster locations that were in shadow (and therefore unfit for reflectance studies). Because some passive measurements were made before or after a laser LIBS shot, the associated timing of the passive observations was also recorded for each entry in the metadata table.

We also used the keywords found in the PDS files to determine instrument pointing and solar position during each observation, which enabled calculation of

incidence, emission, and phase angle. Atmospheric opacity values were provided for each measurement, (interpolated from [4]). This will enable assessment of the effects of atmospheric conditions compared to those when the Sol 76 Target #11 standard spectrum was acquired [1]. Similarly, because signal quality and SNR is affected by detector temperature, the CCD temperature was recorded using the BU_CCD_UV_A file header keyword in the INSTRUMENT_TEMPERATURE group for each observation.

PDS Archive. At the time of writing, the peer review and validation process for the PDS archive elements had been initiated. The archive will include PDS4-compliant files (in XML), and all necessary documentation. After peer review recommendations are adjudicated, final delivery to the PDS will likely occur on or near April 1, 2021. At that time, the CCAM_PROSPECT software will be uploaded to the NASA_GitHub site (<https://github.com/NASA-Planetary-Science>).

Future work. As part of a PDART grant extension, we plan to expand the archived database by including calibrated data and metadata for observations acquired through Sol 2934 of the MSL mission (part of PDS MSL release #26 scheduled for March 16, 2021).

References: [1] Johnson, J.R. et al., *Icarus*, 249, <http://dx.doi.org/10.1016/j.icarus.2014.02.028>, 2015, [2] Johnson, J.R. et al., *Amer. Mineralogist*, 101, 1501–1514, 2016; [3] Johnson, J.R. et al. GSA meeting Cordilleran section, abstract #291933, 2017; [4] Lemmon, M.T., et al., 2019, *Geophys. Res. Lett.* **46**, 9448-9456. DOI: 10.1029/2019GL084407.

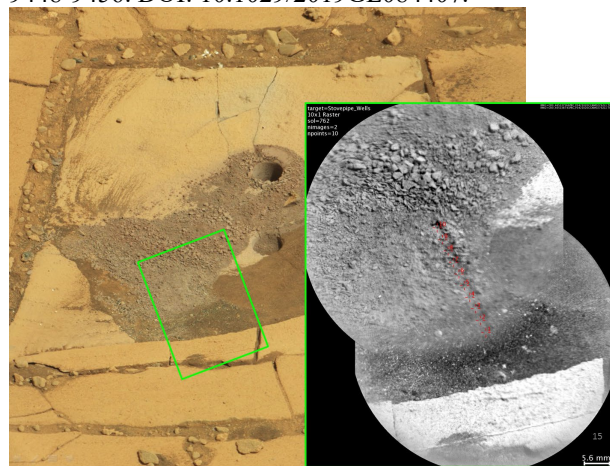


Figure 1. Sol 759 Mastcam M-100 image (0759MR0032680010403804E01) showing Stovepipe Wells target (box) and the Confidence Hills mini-drill and full drill holes, along with Sol 762 RMI mosaic (ccam02762; CR0_465137566/465138741) showing 10x1 ChemCam raster locations numbered in red with crosses designating each target (from [2]).

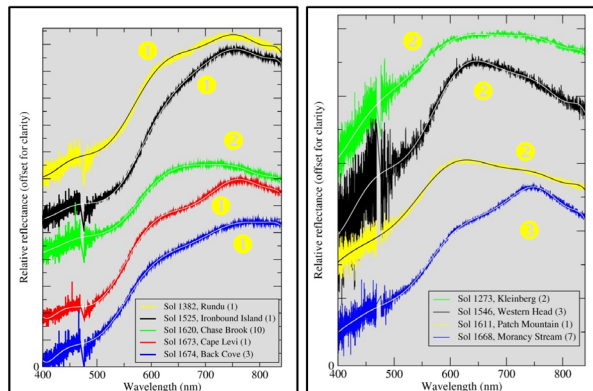


Figure 2. ChemCam spectra (5-channel averages shown as thin lines; spectra offset for clarity). ❶ Typical hematite-like Murray formation rocks with strong, variable Fe³⁺ band depths and slopes, and ~740-780 nm peak positions ❷ Dark patches with shorter-wavelength peak positions and steep slopes toward the infrared, indicative of ferrous materials; ❸ Dark patches with Fe³⁺ features (from [3]).

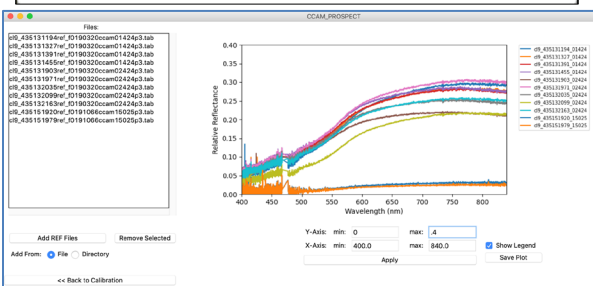
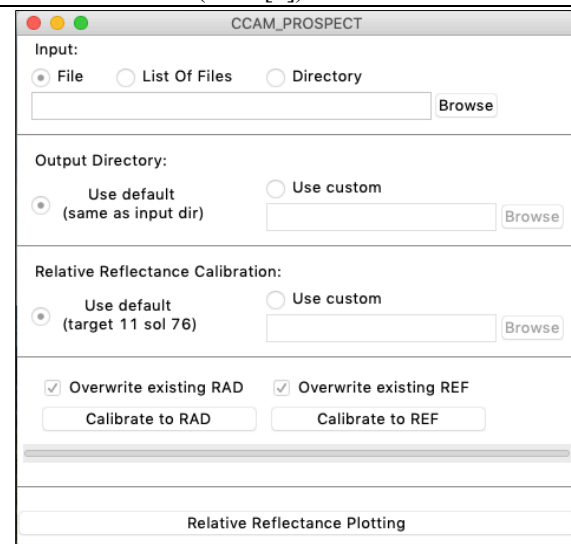


Figure 3. Example of GUI interface for CCAM_PROSPECT software: (top) calibration window; (bottom) plotting window showing relative reflectance spectra.

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