

STATISTICAL VARIABILITY OF CHEMCAM LIBS SPECTRA FROM GALE CRATER EXPLORATION BY CURIOSITY (MSL) : CHARACTERIZING THE SOURCES OF UNCERTAINTIES. Éric LEWIN¹, Pierre BECK², Jérémie LASUE³, Sylvestre MAURICE³, Roger WIENS⁴, the ChemCam team and the MSL team. ¹ISTerre (OSUG : uJF-Grenoble & INSU.CNRS), Grenoble.FR (<Eric.LEWIN@uJF-Grenoble.fr>), ¹IPAG, Grenoble,FR, ³IRAP, Toulouse.FR, ⁴LANL, Los Alamos.NM.USA.

Introduction: The huge spectra collection that ChemCam instrument [Wiens, 2012] has acquired since Curiosity landed at Gale crater contains a wealth of informations that are hard to decipher in details because of the rather high number of phenomena that influence these spectra. However, the reproducibility of these spectra in similar conditions looks quite good. This work is therefore aimed at identifying situations of good reproducibility, permitting afterwards to define quantitatively the level of instrumental reproducibility using the thus selected spectra subsets.

We start at the lowest level of the measurement production. We will first focuss on a few typical measurement sequences for which the targetted material is a priori relatively homogeneous. Among these potential targets are the ChemCam calibration targets, the drill tailings from the different MSL/Curiosity drill operations, and some identified fine-grain soils. On these geological targets, a ChemCam measurement sequence consists usually in a small series of laser shooting locations, and on each location, in a series of laser shots, typically 30, for which each individual plasma has been analysed by the spectroscopic part of the instrument, three spectrometers each with 2048 channels giving three wavelength ranges each with its own spectral resolution.

Available on the Planetary Data System, each acquired spectrum is presented with different levels of treatment [Maurice, 2012]. EDR files give the raw values, as measured, which are unnormalized intensities versus channel numbers. An automated processing chain permits to denoise, to remove the so-called continuum and finally to realign the spectra. The denoise operation permits to improve the statistical aspect the spectra. The continuum-removing operation aims at separating the continuum part (black body radiation and other finer physical phenomena) from the fluorescence part which consists in the series of all the individual spectroscopic lines corresponding to atomic or eventually molecular electronic transitions in the cooling plasma. The third operation consists in realigning these spectroscopic lines with a reference, and therefore calibrating the abscissa from channel numbers into wavelengths. This is necessary since the ChemCam spectrometers are sensitive to Curiosity internal temperature, which varies significantly. The

resulting spectra outing the low-level chain of treatment are named RDR ones. The last low-level treatment consists in correcting for differential optical instrumental "transparency" and sensitivity, relatively to wavelengths by applying a so-called optical transfer function. The resulting spectra are named "CCS" ones.

In order to assess the variability of the spectra at the lowest level, we need to treat with EDR files. However to permit the comparison between spectra measured in different operation sequences, the spectroscopic line realignment is necessary. Each individual EDR spectrum is therefore realigned using the exactly same transformation that was done in the automatic treatment chain, however without the denoise and the continuum removal. Mathematically this looks like changing the abscissa graduation without modifyng the ordinate values. The new set, further called the RAL ones (ReALigned), is statistically studied, and compared through the same statistical tools with the RDR and CCS sets.

The first statistical tool used for this is the relationship between mean values and dispersions. When applied to a sequence of shots from a single location, the difference of relationship for RAL spectra relative to those RDR of CCS shows that the statistical law for the line intensities is different from the one for the continuum. In particular, the former show schematically a simple proportionality between mean value and standard deviation.

Another approach is to recourse to the so call ANOVA, analysis of variance. Because of the omnipresence of martian dust other all measured surfaces, it has been shown [Meslin, 2013] that, for a series of shots at a given location, the few first spectra differ from the remaining ones. The simplest applicatiojn of ANOVA to two subgroups of measurements permits to consider the partitionning of the variance (square of the standard deviation, and an additive parameter) for the whole set, in three parts, the two respective variance for each subset, and the so-called inter-variance, resulting from the difference between the respective means of each subset. Application of this ANOVA technique between the five fist shots and the remaining ones, along the whole spectral range, shows once more a very constricted behaviour between the RAL spectra, with a partition independant of the wavelength for most of them except

a small subset of spectroscopic lines, and the RDR or CCS spectra, where no simple logic seems to emerge from this analysis.

The last statistical tool presented is to look at the structure of the correlation matrix and how this relates to the known physics of spectra as well as

geochemistry, namely by refinding in the statistics, the chemical lines and eventually some of the geochemical so-called correlations such alkaline behaviour (Na & K), or the mafic one (Fe & Mg).