TENSOR COMPONENT ANALYSIS FOR THE INVESTIGATION OF DEPTH TRENDS IN CHEMCAM LIBS DATA FROM GALE CRATER, MARS

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Introduction: Laser-induced breakdown spectroscopy (LIBS) is a multi-elemental analysis technique which uses laser pulses to ablate material from a target. The material evolves into a plasma which emits light corresponding to energetic transitions of the elements in the target. The target can be located several meters away from the laser source, making the method particularly useful for in-situ planetary exploration. The first LIBS instrument employed on an extraterrestrial planet is ChemCam which has been investigating the surface of Mars in Gale crater since 2012 [1,2]. During this time, a very large amount of data was collected: more than 863 000 single shot spectra of more than 3000 individual Martian targets [3]. ChemCam generally operates by doing 30 laser shots at the same position within a raster of several points (5x1, 3x3, 1x10, etc) [3]. The 30 shots at one position enables an analysis with depth, as each shot ablates material slightly deeper in the LIBS crater. Correlation of elemental emission lines among the successive shots can support mineral identification when assuming that elements mainly belong to one mineral phase [4]. Especially interesting in this context are correlations of trace elements, which can substitute for major elements in specific mineral groups [4,5].

Method: In this study, we investigate tensor component analysis (TCA) as a method to analyze depth trends in ChemCam data. A 3d tensor in case of ChemCam data has an observation dimension (the analysis point), a depth dimension (the 30 shots), and a spectral dimension. There are different approaches for TCA, and the one we are following here is parallel factor analysis (PARAFAC) [6,7]. The principle is to decompose a tensor into a sum of low rank one tensors which dimensions are the same as in the original tensor. The principle adapted to ChemCam shot-to-shot data is schematically shown in Fig. 1.

Results/Conclusion: In a first study, non-negative PARAFAC was applied to ChemCam observations identified as felsic composition in [8] (see also [9]). For the computation, functions provided in python's TensorLy [10] package were utilized. The results show, for example, that one rank can be assigned to the dust covering most targets, which is usually blown away after the 5th laser shot. Another rank shows a spectral profile with emission lines of elements expected for alkali feldspars such as Al, Si, K, and Na as well as the trace elements Ba and Rb [5]. This first study on TCA for ChemCam LIBS data demonstrates a great potential for the investigation of depth trends in an unsupervised, data-driven fashion. The simultaneous analysis of depth trends of multiple elements can be a great support for mineral identification.

References:

[1] Maurice et al. (2012), SSR, 170; [2] Wiens et al. (2012), SSR, 170; [3] Maurice et al. (2016), JAAS; 4 [4] Forni et al. (2018), LPSC, #1410; [5] Cousin et al. (2017), Icarus, 288; [6] Kolda and Bader (2009), SIAM, 51; [7] Williams et al. (2018), Neuron, 98; [8] Rammelkamp et al. (2021), ESS, 8; [9] Rammelkamp et al. (2022), LPSC #1999; [10] Kossaifi et al. (2019), JMLR, 20

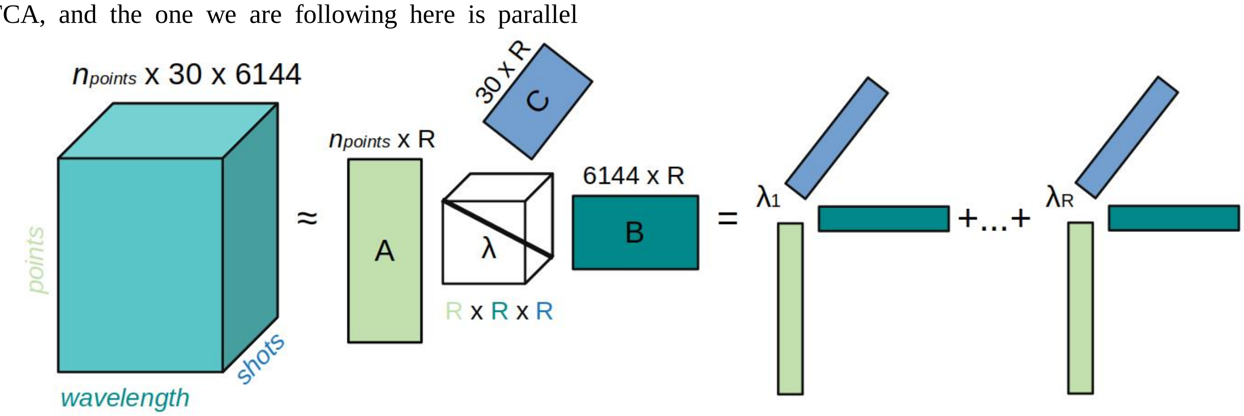

Figure 1: Schematic representation of PARAFAC adapted to ChemCam shot-to-shot data.