Fiber-Induced Raman Signal (FIRS) Analysis from the Perseverance Rover of the Jezero Crater Floor

E. M. Kelly[1], T. Acosta[1], G. Lopez-Reyes[2], M. J. Egan[1], S. M. Angel[3], A. M. Ollila[4], O. Beyssac[5], E. Clavé[6], S. K. Sharma[1], R.C. Weins[7], SuperCam Team. [1]Hawaii Institute of Geophysics and Planetology, the University of Hawaii at Manoa, Honolulu, Hawai'i, [2]Department of Applied Physics, University of Valladolid, Valladolid, Spain. [3]Department of Chemistry and Biochemistry, University of South Carolina, Columbia, South Carolina. [4]Los Alamos National Laboratory, Los Alamos, New Mexico. [5]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, CNRS, Sorbonne Université, Muséum National d'Histoire Naturelle, Paris, France. [6]Centre Lasers Intenses et Applications, CNRS, CEA, Université de Bordeaux, Bordeaux, France. [7]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, Indiana. Correspondence email: evamk@hawaiil.edu

Introduction: The perseverance rover landed on Mars on February 18th of 2021 and was carrying a state-of-the-art spectroscopic instrument called SuperCam. SuperCam can perform VIS, IR, LIBS, and Raman spectroscopies [1]. SuperCam has been utilized in the multi-faceted analysis of the Jezero Crater floor campaign from Sol 0 to at least Sol 400, with Perseverance identifying two distinct formations of the crater floor named Maaz and Seitah. Just above Seitah, lower Maaz shows compositionally distinct material along Artuby ridge [2]. SuperCam contains two different units called the mast unit (MU) and body unit (BU) with the MU containing the 1064 and 532 nm excitation laser as well as a telescope as part of the collection optics. Connecting the two units is a 5.78 m fiber optic cable (FOC) constructed of UV-grade fused silica [1]. The transmission spectrometer (TS) which contains the Raman spectrometer is located in the BU and analyzes the light after it has been collected with the telescope and traveled through the FOC. In the subsequent spectra, a consistent feature is seen in all spectra which ranges mainly from ~ 200 – 500 cm^{-1} as seen in Figure 1. As is demonstrated there, features in the Raman spectrum match those of pristine fused silica glass and are believed to stem from the captured light interacting with the fused silica inside the FOC's core as it travels the length of the cable. The collection angle of the laser and telescope was 180^0 which removes the effect of the phase angle in the signal which occurs due to alignment differences between the light source and collection optics [3]. As such this study looks to analyze the difference in the 532 nm albedo of the Mars targets analyzed with SuperCam Raman to help deepen our understanding of Jezero Crater's floor.

Experimental: To perform the FIRS analysis, 35 of the first 36 Mars Raman targets were chosen, which spanned from Sol 52 to Sol 379. To compare the FIRS features from various targets, the band area from ~ 170 – 600 cm^{-1} was integrated using GramsAI software. Most target spectra were collected over an accumulation time of 0.9 s however some of the earliest targets had lower accumulation times of 4.9 x 10^{-3} s and 0.4s. To correct for this a polynomial fit was used to calculate the expected values if the accumulation times were 0.9s. This value was then divided by the real FIRS intensity to get a ratio for each data point. The average of these ratios was then applied to all FIRS intensities to acquire the new values. Grain sizes were determined via the use of the remote micro-imager (RMI) (minimum resolution 120 μm) located in the MU and confirmed by analyses using SHERLOC and PIXL.

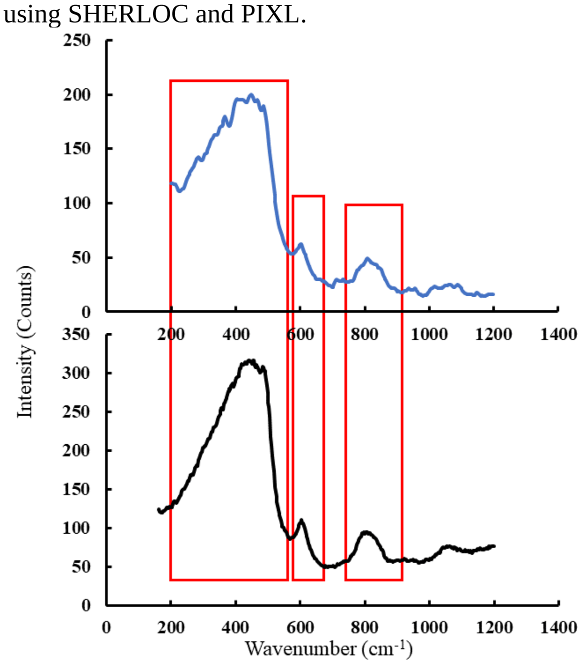

Figure 1: Averaged ICA Raman spectrum of the FOC feature from all Mars targets up to Sol 400 (top) and the Raman spectrum of a fiber identical to the one used on SuperCam acquired in the lab (bottom). Red rectangles highlight the main FIRS features.

Results & Discussion: The band area examined is proportional to the 532-nm light scattered from the target like the bidirectional reflectance examined in previous studies [4]. However, as explained previously, the 180^0 scattering angle removes the effect of the phase angle simplifying reflectance measurements. These computed values can be used in tandem with VIS and LIBS data over the same range as the feature (from

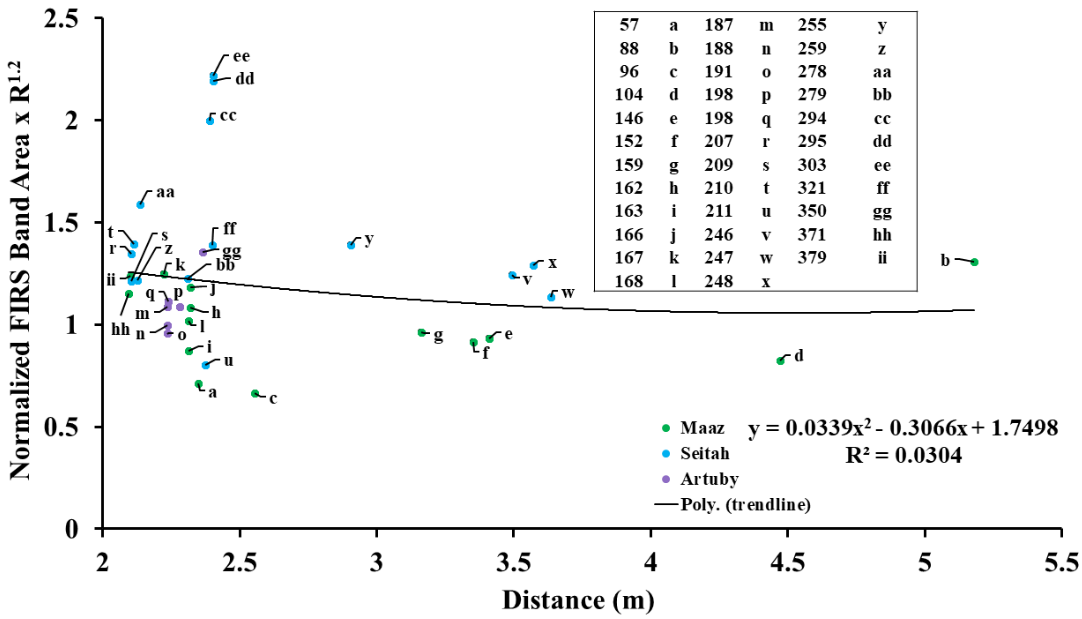

Figure 2: Contains the normalized distance-corrected band area vs the measurement distance in meters. The units for the band area are in counts x m. Maaz, Seitah, and Artuby are represented with green, blue, and purple circles, respectively. The black trend line is applied to all three types of samples. The individual targets are labeled with letters that correspond to the Sol on which the target was observed.

~532 – 549.5 nm) to help confirm the optical constants of the targets in question [5].

Figure 2 illustrates the change in band area of the FIRS signal as a function of distance. The variation in the FIRS from samples at similar distances reflects the difference in mineralogy between the samples as dictated by their different albedos due to differences in the refractive indexes of the mineral matrices. The difference in albedos can differ from a few factors beyond mineralogy, including grain size and elemental composition.

An examination of the grain size averages (taken from at least 5 individual measurements per target) found a negative correlation with the integrated band areas. The upper and lower grain averages gave slopes of $y = -45.337x + 27e4$ and $y = -94.517x + 28e4$, respectively. The values with the highest intensities were those from a set of targets called Quartier from Sols 294 – 321 which happened to also have some of the smallest identifiable grain sizes (312 – 156 µm in diameter). Grains of smaller sizes could not be identified due to the limitation of the RMI resolution. It should be mentioned that the Quartier samples were of an abraded target, however, targets with similar grain sizes (including abraded target) gave lower values showing this difference is due to composition rather than grain size.

Another point of interest is the difference in the FIRS band area intensities with the Seitah formation giving the highest intensities in both Figure 1 and when comparing grain sizes. This trend was seen in targets that were determined to be similar in grain size pointing to a mineralogical difference that was independent of grain size. This is likely due to the difference in the mineralogy of the Maaz having feldspars compared to the more olivine-rich Seitah [6]. The green olivine grain gives a higher reflectivity/albedo causing the Seitah targets to fall above the curve.

Conclusions: The FIRS band areas contain information on the albedo of the targets analyzed, showing differences between the different formations as well as targets. These differences are independent of distance and grain size and are a result of the mineralogy of the targets in question. The intensity of the band areas increases with distance as more scattered 532nm-laser light is captured by the spectrometer's field of view. Insights into the FIRS feature could aid in understanding the mineralogy of various geological units within Jezero Crater and warrants further investigation.

References: [1] *Wiens, R. C. et al. (2020) Space Science Reviews, 217 (1), 4.* [2] *Wiens, R. C. et al. (2022) Science Advances, 8(34)9* [3] *Lucey, P. G., et al. (2014) JGR: Planets, 119(7), 665-1679.* [4] *Lucey, P. G. (1998) JGR: Planets, 103(E1), 1703-1713*. [5] *Arnold, J. A. et al. (2014) Amer. Mineral., 99(10), 1942-1955*. [6] *Mandon, L., et al. (2022) JGR: Planets.*