A SEMI-QUANTITATIVE ANALYSIS OF BIG SKY APXS SCATTER PEAKS. D. Tesselaar[1], G.M. Perrett[2], R. Gellert[1], J.L. Campbell[1], and the APXS Team, [1]University of Guelph, Guelph, Ontario, Canada. [2]Cornell University, Ithaca, NY, U.S.A.

Introduction: The Alpha Particle X-ray Spectrometer, or APXS, aboard the Curiosity rover is a third generation instrument used to determine the elemental composition of Martian rocks and soils. Mounted on Curiosity's turret, the APXS is deployed *in situ*, obtaining an energy-dispersive X-ray spectrum of a target through a combination of particle induced X-ray emission and X-ray fluorescence [1]. Due to X-ray attenuation effects, the APXS can only directly measure elements from Na (Z=11) to Y (Z=39), and a few trace elements present in sufficient quantities at higher Z. Aside from cation-bound oxygen, typically present as 40-50 wt% of a sample, other low Z elements (H to Ne) which may contain geologically interesting components (carbonates, water, fluorides, etc), cannot be detected directly by the APXS. Although detection of low Z elements are not directly represented in APXS spectra, they do influence the Compton and Rayleigh back-scattered Pu X-rays.

Work has been done in the past with MER APXS scatter peaks to quantify invisible components in Paso Robles [2]. Recent work has calibrated this scatter peak method to the MSL instrument using the terrestrial calibration suite [3,4]. The goal of this work is to present a semi-quantitative scatter peak analysis of the recent Big Sky targets in relation to geochemically similar soil targets to show that Big Sky has unique scatter peak signature which may indicate the presence of elevated low Z elements.

Theory: For a given target, the ratio of the experimental Compton and Rayleigh peak-areas is referred to as a C/R ratio. It is known that that the experimental C/R ratio is a monotonically decreasing function of the mean atomic number [3]. Therefore, increasing the concentrations of low Z elements will decrease the mean atomic number while increasing the experimental C/R ratio. Since the characteristic X-rays of the low Z elements are not visible in APXS spectra, the presence of these low Z components can only be inferred by computing a theoretical C/R ratio based on the elements visible in the APXS spectrum.

The quantity used to compare the theoretical and experimental C/R values is their ratio, defined as K. If the sample chemistry is known precisely, and the theoretical C/R is reliable, then the K-value should be unity. If there is an appreciable amount of low Z elements in a sample, the experimental C/R will increase, causing the K-value to decrease. It is in this way that an excess of invisible components relative to cation-bound oxygen can be identified.

One important caveat worth noting is that the K-value seems to follow a linear trend with the fraction of oxygen present in samples [4]. The underlying physics of this trend is unclear; however, it will be used to constrain the analysis and comparisons of Big Sky to targets with similar elemental chemistry.

Big Sky and Martian Soils: Big Sky is a target which is part of the Stimson sandstone unit, first encountered by Curiosity around Sol 1000. This target located near Bridger Basin, adjacent to silica enriched fracture zones, and is thought to be a relatively unaltered sandstone. Through sols 1114-1132, the APXS was used to characterize the rock, as well as its drill tailings, and its pre and post sieve dump piles.

Figure 1: *Location of Big Sky in Bridger Basin. (NASA/JPL-Caltech)*

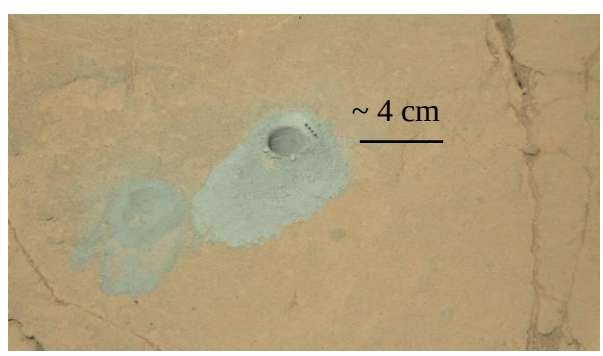

Figure 2: *Big Sky drill tailings imaged by Mastcam on sol 1126.*

To provide context for an interpretation of Big Sky K-values, it is necessary to define a control group of similar composition. It was found that the Big Sky tar-

gets are most chemically similar to the soils found in Gale Crater. The targets chosen for this comparison are Argyle, Lagrange, Sourdough, Kelso, and Dumont. These soil targets have relatively minor variations in their chemistry and also have long APXS integration times and were sampled with small standoffs at cold temperatures, providing good statistics for the elements and scatter peaks.

To provide evidence that the composition of the soil and Big Sky targets were similar in composition, the average concentrations were calculated for the soil group and for the Big Sky targets. The ratio of the average Big Sky composition to the average soil composition is plotted in figure 3. Note that figure 3 shows

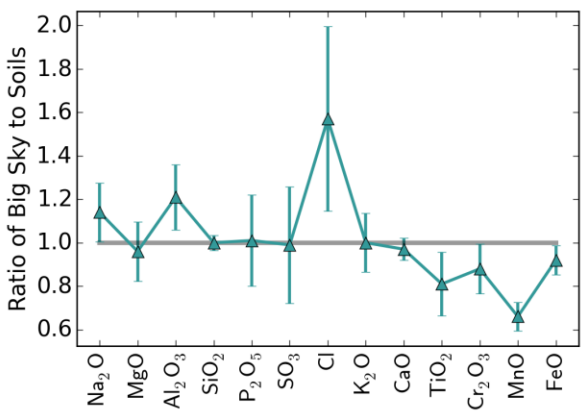

Figure 3: *Ratio of the average Big Sky composition to the average soil compositions for abundant elements. Uncertainties plotted are the standard deviation at 1σ.*

relatively good agreement between the two groups. The elements that show poor agreement are typically present in small amounts, such as chlorine and manganese. These therefore contribute little to the overall C/R ratio. Furthermore, the mean fraction of oxygen was found to be equivalent for both target groups, with Big Sky at 42.5±0.5 wt%, and the soils at 42.3±0.3 wt%.

K-Values: Using the fitting software GUAPX (based on GUPIX [5]) to fit the spectra, elemental compositions and experimental C/R ratios were obtained for the Big Sky and soil target groups. Using the fitted elemental compositions, the theoretical C/R ratios were calculated by CRAM, an analytic C/R calculator recently developed at the University of Guelph [6]. Using the experimental and theoretical C/R ratios, K-values were calculated for both target groups. Since the chemistry of the groups is close to the same it is expected that the K-values should be the same; however, Figure 4 shows that this is not the case. The mean K-value for the soil targets is 0.961±0.008, and the mean K-value for the Big Sky Targets is 0.907±0.009. The composition of the visible components of the two groups is too close to account for the significant difference in K-values. Since the mean Big Sky K-values are significantly smaller than the soil K-values, this indicates that there is likely some amount of an unknown invisible component. Possible candidates may be bound water, carbonates, fluorine, or any combination of light elements.

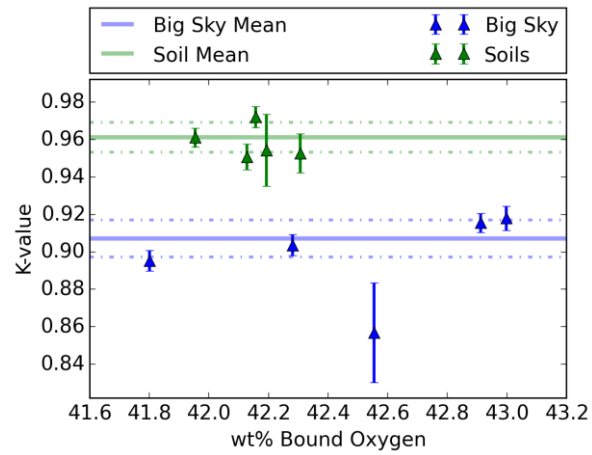

Figure 4: *K-values for soil and Big Sky groups plotted against fraction of oxygen. Uncertainties are experimental and are 2σ.*

Conclusions: The APXS Compton and Rayleigh scatter peaks are sensitive to the mean atomic number of a given sample and contain information about the invisible low Z components that may be present. By means of K-value analysis, one can use the scatter-peaks to identify the presence of invisible components. Given the similar sample compositions, K-value analyses indicates that, relative to average Martian soils, the Big Sky targets may contain elevated invisible components.

References: [1] R. Gellert et. al. (2006) JGR 111(E2):1-32 [2] J.L Campbell et. al. (2007) [3] J.L. Campbell et. al. (2008) [4] Glynis M. Perrett et. al. (2015) [5] J.A. Maxwell et. al. (1995) [6] D. Tesselaar M.Sc. Thesis, University of Guelph (2015)

Acknowledgements: The MSL APXS is financed and managed by the Canadian Space Agency (CSA) with MacDonald Dettwiler and Associates (MDA) as the primary contractor to build the instrument. Funding is provided by the CSA and NASA. Much appreciation goes to JPL for their support, dedication and invaluable expertise.