APXS RASTER LOCALIZATION USING MAHLI-DISTINGUISHABLE PHASES. S.J. VanBommel[1], R. Gellert[1], L.M. Thompson[2], J.A. Berger[3], N.I. Boyd[1], J.L. Campbell[1], K.S. Edgett[4], M.E. Minitti[5], M.E. Schmidt[6], A.S. Yen[7], and the MSL Team, [1]University of Guelph, Guelph ON, Canada, [2]University of New Brunswick, Fredericton NB, Canada, [3]University of Western Ontario, London ON, Canada, [4]Malin Space Science Systems, San Diego CA, USA, [5]Planetary Science Institute, Tucson AZ, USA, [6]Brock University, St. Catharines ON, Canada, [7]California Institute of Technology, Pasadena CA, USA.

Introduction and Rationale: The Alpha Particle X-ray Spectrometer (APXS) on the Mars Science Laboratory (MSL) rover, *Curiosity*, is an arm-mounted bulk chemistry instrument that performs high-precision in-situ measurements of rocks and soils [1]. Compared to the Mars Exploration Rover APXS, the MSL APXS is 5x more sensitive and has a Peltier cooler that improves the nominal ambient operational temperature from -40^o C to -5^o C [1, 2]. The increase in sensitivity and improved integration during warmer temperatures allows the APXS to characterize a larger area than its nominal field of view (FOV) by utilizing a raster technique. Morning or evening rasters can be used to investigate sample heterogeneity (compositional and/or textural) on the order of the APXS FOV.

Arm-mounted instruments, including the APXS, have placement uncertainty (accuracy <15 mm; precision <10 mm) [3]. Arm placement adds uncertainty to the interpretation of APXS data given an in-contact APXS FOV of ~15 mm [1]. Here, we combine APXS data with images from the Mars Hand Lens Imager (MAHLI) to constrain APXS positioning on the Martian targets Sayunei, Stephen and Morrison (Fig. 1).

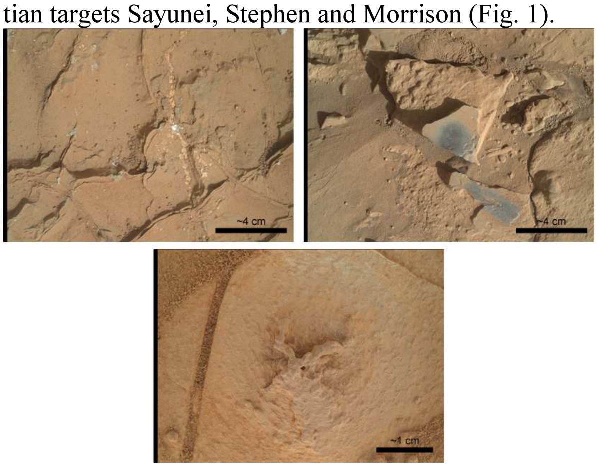

Figure 1: *MAHLI images of APXS raster targets Sayunei (top left, sol 165), Stephen (top right, sols 627-629) and Morrison (bottom, sols 767-779).*

Method: MAHLI images were analyzed by classifying pixels into orthogonal bins based on the assumption that visually distinct phases have a distinct APXS composition. The orthogonality correlates directly to elemental and/or spectral variation observed in the APXS data. The APXS raster FOVs are overlaid on the MAHLI image. The positional assumption, given identical MAHLI and APXS targets, is that the central APXS FOV is aligned with the center of the MAHLI image. The pixels within each APXS FOV are analyzed and tabulated based on their radially dependent contribution resulting in a relative abundance of each phase for each APXS FOV. The test raster is translated and/or rotated to assess a different orientation. The linear relationship between phase abundances and the appropriate APXS spectral variation is compared using a bivariate weighted least squares regression [4] to infer a more-likely APXS raster position and orientation.

Sayunei is a mudstone from the Yellowknife Bay area (John Klein class [5]) with a cross-cutting vein. APXS data collected from a 2x2+1 raster showed elevated CaO and SO_3 in three of the five raster positions and was complimented by MAHLI images of the central APXS spot only [6]. This light-toned vein material is visually distinct, resulted in CaO and SO_3 variation in the APXS spectra and is interpreted to be $CaSO_4$. As the amount of vein material in the APXS FOV increases, the SO_3 measured by the APXS will increase. This linear relationship between vein material (light-toned pixels) and SO_3 (wt%) was used to infer an APXS raster position that not only agrees with proportionality but also with upper- and lower-limit bounds (Fig. 2).

Stephen is a thin fracture fill/layer within silt/sandstone at the Kimberley waypoint. APXS data collected from a 2x2+1 raster showed variation in the APXS norm (proxy for instrument standoff) as well as dust-dependent signals. The APXS raster was complimented by 5 cm MAHLI images on the all raster spots. Pixels from the MAHLI image(s) were classified as either dust, rock or negligible based on pixel saturation level and sample topography. A combination of elemental and topographic linear relationships was used to infer a more-representative APXS raster position (Fig. 3).

Morrison is a brushed, raised, diagenetic feature at the Pahrump waypoint [7, 8]. APXS data obtained via a 2x2+1 raster showed elevated MgO, SO_3, Ni and, to a lesser extent, Cl and Br in the diagenetic feature relative to the immediately adjacent bedrock [7, 8]. MAHLI images of the target were taken on earlier sols of the central APXS raster spot only. As with Stephen, a ternary pixel classification system was used on Morrison, binning pixels orthogonally as dust, bare rock or rosette, with various linear correlations to spectral heterogeneity observed in the APXS data.

Results and Observations: Improved positioning of APXS rasters through MAHLI pixel analysis resulted in significant shifting (4-8 mm) of the APXS raster center from the center of the MAHLI image considering the size and sensitivity of the APXS's FOV. APXS placement deviation from the center of MAHLI images is comparable to observed offsets of a Dust Removal Tool brushed center and a post-brush MAHLI image center (i.e. ~3 mm offset on sol 755 Maturango). The APXS raster edges are not parallel to MAHLI image edges as confirmed when MAHLI images are acquired on each APXS raster spot.

APXS raster positioning for Sayunei exists within arm placement uncertainty such that the elevated CaO and SO_3 observed is attributed to the vein material and is not elevated in the host rock (Fig. 2). Combining target topography and visually distinct phases improved the Stephen raster location (Fig. 3, rotation was minimal as initial orientation was dictated by MAHLI images of each APXS raster location). The best-agreement raster offsets from MAHLI image center for Sayunei and Stephen are in the same direction, despite the flipped arm orientation between the two locations, hinting perhaps at a systematic placement error (Fig.4). A preliminary analysis of the Morrison raster indicates strongly that the APXS raster is offset from the MAHLI image center as well.

Conclusions: APXS rasters are a powerful tool for quickly analyzing heterogeneous samples. MAHLI images with visually distinct phases can reduce APXS FOV uncertainty, ultimately improving interpretation of the target and its geological context.

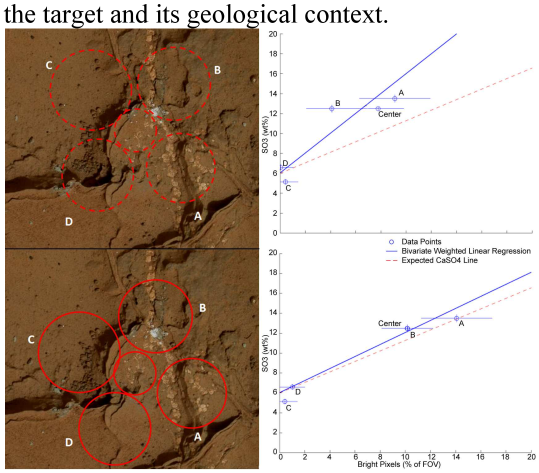

Figure 2: *Early raster position (top, raster parallel to MAHLI image edges and centered on 5 cm MAHLI image) and improved raster position (bottom) yielding a strong correlation between vein material in the APXS FOV and APXS SO_3 concentration (wt%). For scale, the central APXS FOV diameter is ~15 mm.*

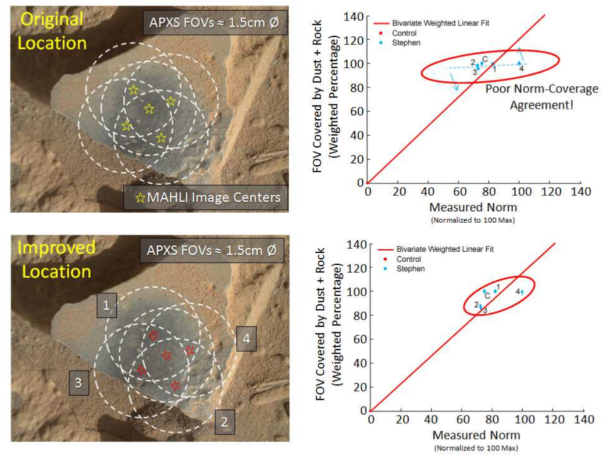

Figure 3: *Raster position yielding an improved correlation between radially weighted APXS FOV pixel fill and measured APXS norm. The updated position also improved the correlation between dust-related signals and the amount of dust in the APXS FOV.*

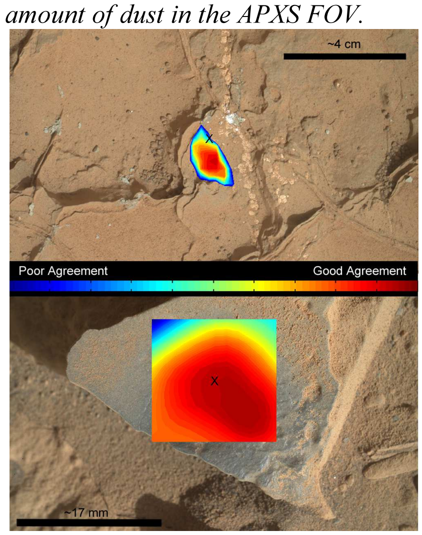

Figure 4: *Correlation plots of Sayunei (top) and Stephen (bottom) illustrating a raster center offset of ~8 mm and ~4 mm respectively from the appropriate MAHLI image centers (marked by X) to the region of best agreement (dark red).*

References: [1] Gellert et al. (2014), LPSC XLV, #1876. [2] Gellert et al. (2006), JGR, 111-E2. [3] Robinson et al. (2013), IEEE SoSE, 184-189. [4] York et al. (2004), AJP, 72-3. [5] Schmidt et al. (2014), LPSC XLV, #1504. [6] McLennan et al. (2013), Science, 1244734. [7] Thompson et al. (2015), LPSC XLVI (this meeting). [8] Gellert et al. (2015), LPSC XLVI (this meeting).

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