HyPyRameter: A PYTHON TOOLBOX TO CALCULATE HYPERSPECTRAL REFLECTANCE PARAMETERS. M. S. Phillips[1], J. E. Moersch[2], U. Basu[2], and C. W. Hamilton. [1]Johns Hopkins Applied Physics Laboratory (Michael.Phillips@jhuapl.edu), [2]The University of Tennessee, Knoxville, [3]The University of Arizona.

Introduction and Motivation: Many minerals, including Fe-bearing silicates, phyllosilicates, amorphous silica phases, carbonates, sulfates, and oxides, display diagnostic absorption features in visible to short-wavelength infrared (VSWIR) reflectance spectra [1]–[3]. Thus, reflectance spectrometers are excellent tools for mapping planetary surface compositions [4]–[13]. Field-deployable hyperspectral push-broom imagers capable of collecting data at the outcrop-scale [14], [15] and landscape-scale from a nadir-pointing drone-mounted platform [15] have recently expanded the potential for field-applications of hyperspectral reflectance spectroscopy.

One issue with hyperspectral datasets is that they are not readily interpretable. Hyperspectral image cubes contain an immense amount of information that can be difficult to display in a meaningful manner. One solution is to parameterize characteristics of a spectrum [16], [17]. "*Spectral parameters*" can be formulated for specific absorption bands and other features associated with compositions of interest. A gray scale spectral parameter image can be returned that is bright where a composition is present and dark where it is not – a form of the data that is readily interpretable. Thematically related spectral parameter images can be combined into 3-band color "*browse products*" (e.g., Fig. 1).

Here, we present first results from the HyPyRameter Python toolbox that calculates spectral parameters for hyperspectral image cubes and point spectra in the VSWIR spectral region. The tool has been beta-tested on hyperspectral images from a HySpex Mjølnir VS 620 (hereafter, HM) imager (3.0-5.1 nm spectral sampling) and spectra from a Spectral Evolution OreXpress point spectrometer (2.8-8.0 nm spectral sampling).

Methods: We used CRISM spectral parameters [17] as a starting point for HyPyRameter. We included spectral parameters sensitive to Fe-bearing silicates, phyllosilicates, hydrated silica, carbonates, sulfates, and oxides. The CRISM parameters that extend beyond the wavelength region of our instruments (400-2500 nm) were not included in the HyPyRameter library. Additionally, we formulated several new parameters sensitive to Fe-bearing oxides, elemental sulfur, and chlorophyll (e.g., SH460, BD670, D700, BD875, and ELMSUL). In total, 12 visible to near infrared (VNIR, 400-1000 nm) and 27 short-wavelength infrared (SWIR, 1000-2500 nm) parameters are included in the current version of HyPyRameter. Parameters are calculated on VNIR and SWIR data independently because it is common for hyperspectral reflectance imaging systems

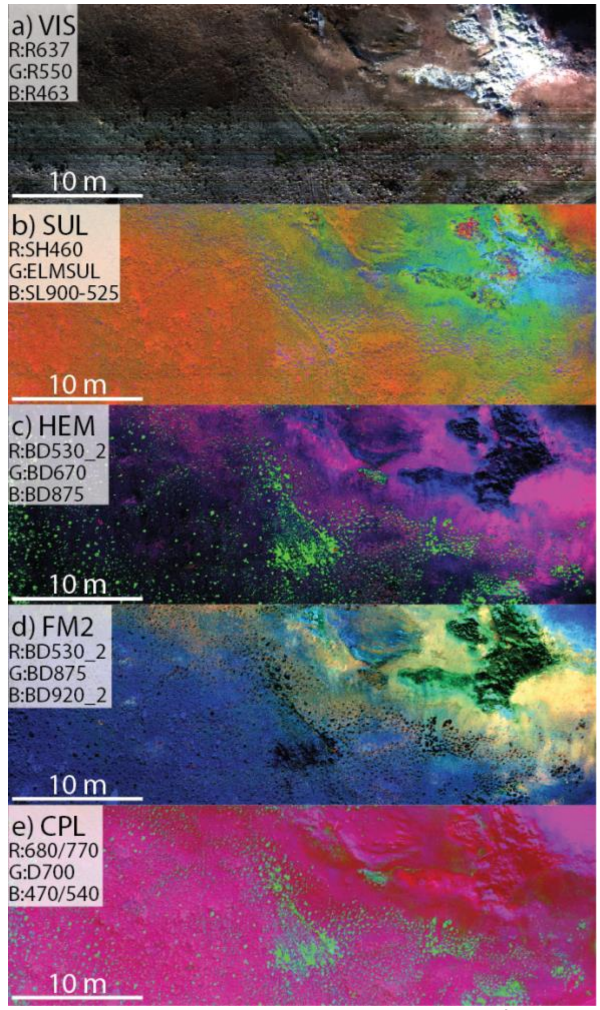

Figure 1 | Browse product images calculated from a visible near-infrared hyperspectral image cube captured using the drone-mounted HM imager. a) Approximate true color. The bright white area is the main hydrothermal vent site. b) sulfur (SUL) browse product highlighting elemental sulfur in green, yellow, and cyan. c) hematite (HEM) browse product highlighting hematite in pink/purple. d) Fe/Mg-oxide (FM2) browse product highlighting hematite in yellow/green and goethite in cyan. e) chlorophyll (CPL) browse product highlighting chlorophyll in green. Plants comprise the majority of detections, but microbial mats can be observed in the top-middle and top-right of the scene.

to be sensitive to either the VNIR or SWIR (and not both) or to comprise separate detectors for each wavelength region. Additionally, parameters were formulated to adaptively select spectral channels nearest

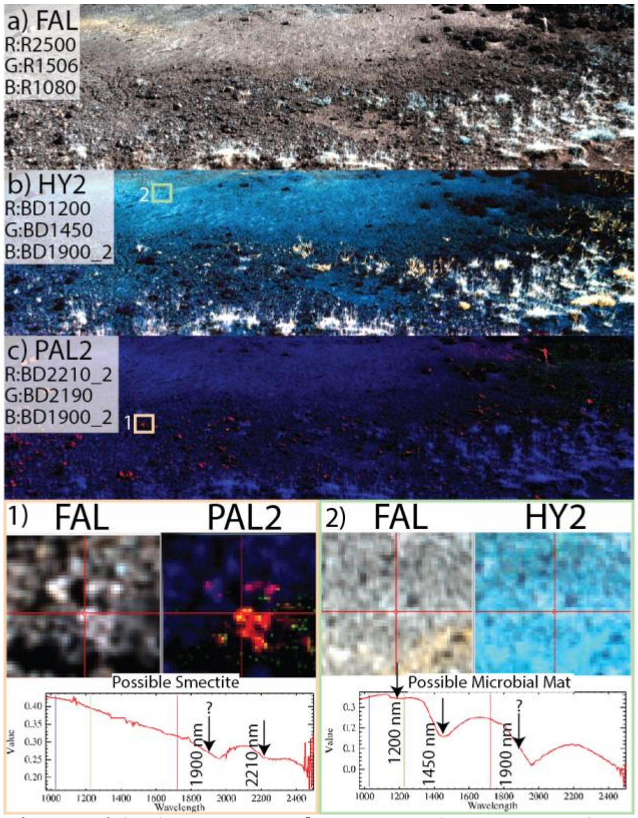

Figure 2 | (a-c) Browse product images (~15-m across) calculated from short-wavelength infrared data acquired with the HM imager on a tripod-mounted scan platform. a) FAL – false color product. b) HY2 – hydrated materials browse product highlighting plants (white/orange), microbial mats (bright green/white to bright orange/white) and damp soil (blue/cyan). c) PAL2 – aluminum-bearing phyllosilicate browse product highlighting a possible aluminum-bearing smectite phase in red to yellow. Zoom window and spectrum of 1) possible Al-bearing smectite and 2) possible microbial mat.

to the wavelength of interest for each calculation. Therefore, the HyPyRameter toolbox can be flexibly applied to many VSWIR hyperspectral data products with the appropriate wavelength range (400-2500 nm) and spectral sampling.

Results: The HyPyRameter toolbox was tested on OreXpress point spectra collected in the field in support of the Rover-Aerial Vehicle Exploration Network (RAVEN) Iceland field campaign [18] and on HM image cubes collected at a hydrothermal vent near Namafjall, Iceland [19]. HM data were processed to reflectance using the empirical line method and noise was remediated through an inverse minimum noise fraction transformation process [20] prior to calculation of spectral parameters.

Spectral parameters were calculated in Python using the paramDriver.py script from the HyPyRameter toolbox. The script produces 3-band browse products saved as PNGs as well as multiband, ENVI-readable image cubes containing all parameters calculated for either the VNIR or SWIR wavelength regions.

Results calculated on a VNIR image cube collected overhead with the drone-mounted HM imager are shown in Figure 1. Absorption features in the VNIR wavelength region highlight elemental sulfur (green and yellow in Fig. 1b), oxides (purple in Fig. 1c; green, yellow, and cyan in Fig. 1d), and chlorophyll (green, Fig. 1c,e). Results are also shown from a SWIR image cube collected with the HM imager mounted on a motor-controlled pan-tilt tripod platform. The SWIR wavelength region highlights differences between various hydration states (Fig. 2b) and hydrous minerals, such as smectites (Fig. 2c). Plant material and microbial mats contain hydration bands at 1200, 1450, and 1900 nm, but moist ground typically shows only the 1900-nm absorption feature and, to a lesser extent, the 1450-nm feature. A possible aluminum-bearing smectite phase was observed and is highlighted in red in Figure 2c.

Conclusion: Spectral parameters are useful for highlighting materials with known absorption features. The HyPyRameter toolbox has enabled quick production of spectral parameters and browse products from hyperspectral reflectance image cubes and point spectra tested in a mock rover mission scenario [18]. HyPyRameter has applications for geology, agriculture, mining, and beyond.

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