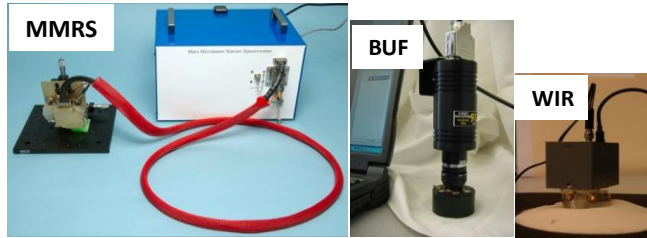


AN INSTRUMENT SUITE FOR MINERAL ID AND BIOMARKER SEEKING IN ATACAMA. Alian Wang¹, James Lambert², Pablo Sobron³, and the Life in the Atacama Project Team,¹Dept. of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University in St. Louis, One Brookings Drive, St. Louis, MO, 63130, USA; ²Jet Propulsion Laboratory, California Institute of Technology, ³Space Science and Technology, Canadian Space Agency; (alianw@levee.wustl.edu).

Figure 1. An instrument suite with three active sensors



Introduction: During the first year field expedition of ASTEP project, *Life in the Atacama* (May 2012), we brought an instrument suite, a laser Raman spectrometer (MMRS), a near IR spectrometer (WIR), and an UV-stimulated fluorescence imager (BUF), to conduct in-situ mineral and bio-signature identification (Figure 1).

Throughout the expedition, our instruments were deployed in several locations, with working conditions ranging 0 to 4,500 m elevation, -2 °C to 38 °C temperature, and 3.5% to 83% relative humidity. All three sensors in this instrument suite performed well and produced good quality data (Figure 2); details will be reported and discussed at the conference. A manuscript on the mineralogy and chemistry characters of a specific location at Valle de los Dinosaurios, near San Pedro de Atacama, Chile, has been submitted [1].

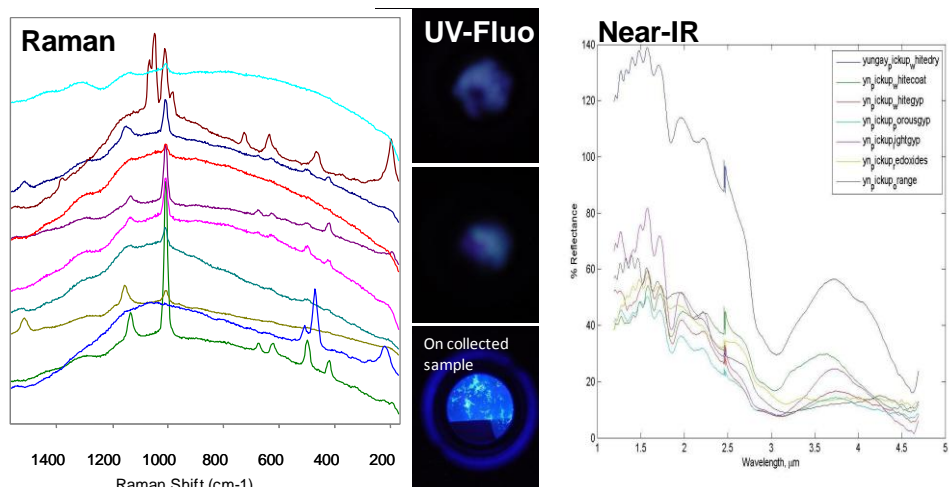
Three active sensors: This instrument suite represents a new concept for *in situ* optical sensing for detailed scientific investigations in the next generation of planetary exploration missions. They are all *active optical sensors*, i.e., the sensors incorporate their own light sources for excitation which allow an optical configuration with well-defined optical paths and viewing geometry for signal generation and collection. The atmospheric fluctuation and thermal emission from surface materials that frequently affect the detection sensitivity of orbital and stand-off measurements are thus minimized in our suite. This optical configura-

tion ensures repeatable measuring conditions for surface samples and calibration targets.

For this *Life in Atacama* ASTEP project, the synergistic applications of three internally correlated spectroscopic sensors, MMRS, WIR, and BUF, would enhance the science return. For example, while both MMRS and WIR enable ID of molecular species, the two sensors show different sensitivities for different types of minerals as light-matter interactions obey different spectroscopic selection rules. BUF selectively observes the fluorescence potentially generated by bio-genetic species, which can be correlated with the fluorescence-induced background signals that might appear in the Raman spectra from the same sample obtained by MMRS. Based on our extensive laboratory study of extraterrestrial materials and terrestrial field studies, we believe that *this instrument suite represents one of the best combination for in situ mineral and bio-signature ID in a planetary surface and subsurface exploration [1-9].*

MMRS in this instrument suite: MMRS (Mars Microbeam Raman Spectrometer) is an *in situ* laser

Figure 2. MMRS spectra, BUF images, and WIR spectra obtained in Atacama field



Raman sensor, developed by a combined team at Washington University in St. Louis and at Jet Propulsion Laboratory [2, 3, 4], supported by NASA PIDD, MIDP programs, Athena payload development, and by the internal funding from our institutions. It is designed to be deployed by a robotic arm on a planetary rover or lander. *MMRS* has a high TRL and was ranked *category one* during the payload selection review for the Mars Science Laboratory (MSL) mission.

Minerals and organic functional groups all have fingerprint Raman spectra. Raman peaks are sharp, show little to no overlap, and are essentially free of overtones and combinations, thus are most suitable for unambiguous phase identification. The MMRS laser does not vaporize the materials that makes the measurement is non-destructive. The laser beam and the scattered Raman photons can penetrate through optically transparent windows on a sample container that makes the measurement to be non-invasive.

Four major features of MMRS ensures the best Raman performance for planetary exploration: (1) a narrow beam with linear scan capability; (2) a high spectral resolution with wide spectral range; (3) a large depth of sampling field; (4) a suitable excitation laser wavelength for characterization of minerals, organics, and bio-markers.

WIR in this instrument suite: WIR (Water-IR spectrometer) is an *in situ* Near-IR reflectance spectrometer, developed at Washington University in St. Louis through the support of NASA ASTID program and WUSTL internal fund [6-9]. It is designed to be deployed either by a robotic arm on planetary rover or lander, or to be installed in the wheel of a rover for rapid phase ID along the wheel track. During the development of a Discovery mission proposal in 2011, the most critical component of WIR, the IR detector, passed the tests on radiation for space flight and demonstrated an operation temperature range down to -33 °C.

The current WIR_v3 has a mass of 294 grams, a size of 7.5 x 7.5 x 5 cm, and average power consumption of 3.3 W. The sensitivity tests demonstrated that ~1 mole % carbonate, 0.5-1 mole% of sulfate, 0.5 -1 mole % of OH-bearing species diluted in a quartz matrix were detectable in a 30 second WIR measurement.

The spectral range and spectral resolution of WIR (1.14 – 4.76 μm, 0.14 nm/pixel) was selected specifically to look for the presence of H₂O/OH bearing species and biomarkers. Four features make WIR stand out among other IR system: (1) a spectral range of 1-5 μm permits WIR to directly detect water in different forms (liquid, ice, or clathrates, structural H₂O and OH, and water adsorbed on grain surfaces), carbonates, sulfates, hydrated silicates, as well as C-H & N-H bonds in organic species; (2) multiple active IR sources produce strong reflectance spectrum from sample surface that will not be affected by the thermal emission from the samples; (3) direct deployment on unprepared samples (FOV ~ 1 cm); (4) Highly sensitive IR detector for fast measurement (1s to 2 minutes).

Before this trip to Atacama in May 2012, WIR was tested during a 2008 field expeditions to Tibet Plateau

(China) and 2011 AMASE expedition to Svalbard (Norway). Excellent spectra were obtained.

BUF in this instrument suite: BUF is a fluorescent imager using active UV sources (370 nm) irradiating the surface of a sample. The basic principle of BUF is that the wavelength of the stimulated fluorescence radiation can be used to distinguish roughly biogenetic species from inorganic materials [4].

A set of BUF measurements of >150 samples of martian meteorites, lunar rocks, terrestrial rocks and minerals, coral and shells, fungi and spores, and other bio-genetic species demonstrated that they can be classified into three groups according to the general strength fluorescence signals and the relative intensities of color components in the fluorescence signal. Samples in **Group 1** show NO or extremely weak fluorescent emission, which include martian meteorite EETA79001, lunar rock 75075,154, seven fresh or slightly altered terrestrial igneous rocks three terrestrial metamorphic rocks, and four samples of sedimentary origin, and mineral grains of hematite, kyanite, orthoclase, and tourmaline. Samples in **Group 2** show strong fluoresce in the blue and green portions of the spectrum, which includes fungi and spores, corals and sea-shells, dry plants, animal bones, travertine, and two amino acids. Samples in **Group 3** have less intense fluorescence and a weaker green component than red and blue components, which include a hydrothermally altered basalt, a slightly weathered granite, acid alteration products from a Hawaii basalt, several carbonate rocks of biogenetic or non-biogenetic origins, some clay minerals (kaolinite, saponite), two sea-shells, and a few minerals containing fluorescing elements (Cr³⁺, Sm³⁺, Mn²⁺). Three lunar rock samples (76135,29, 78235,20, and 77035,58) enriched in REE also belong to this group.

The current optical head of BUF-v2 has a mass of 100 grams, a size of 5 cm (diameter) x 3.5 cm (height), and a FOV ~ 1.2 cm (diameter). It takes an image in 2 – 8 seconds, depending on the types of samples. A flight model of BUF can be built using all flight hardware (LED, filter, CCD, electronics).

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References: [1] Sobron et al., 2012, GRL; [2] Wang et al. (1998) *Applied Spec*; [3] Wang et al. (2003) *JGR*; [4] Wang (2012), LPSC; [5] Wang et al. (2003), LPSC; [6] Wang et al. (2004), LPSC; [7] Sobron et al. (2009), LPSC; [8] Wang et al. (2010), LPSC; [9] Sobron et al. (2011), LPSC.