

**THE DEVELOPMENT AND FIELD TESTING OF THE PORTABLE ACOUSTO-OPTIC TUNABLE FILTER SPECTROMETER FOR ASTROBIOLOGY.** N. J. Chanover<sup>1</sup>, K. Uckert<sup>1</sup>, D. G. Voelz<sup>2</sup>, and P. J. Boston<sup>3</sup>, <sup>1</sup>Department of Astronomy, New Mexico State University, Box 30001/MS 44500, Las Cruces, NM 88003, [nchanove@nmsu.edu](mailto:nchanove@nmsu.edu), <sup>2</sup>Klipsch School of Electrical and Computer Engineering, New Mexico State University, Box 30001/MS 3-O, Las Cruces, NM 88003, [davvoelz@nmsu.edu](mailto:davvoelz@nmsu.edu), <sup>3</sup>Earth and Environmental Sciences Department, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801, [pboston@nmt.edu](mailto:pboston@nmt.edu).

**Introduction:** The development of *in situ* instrumentation for the detection of biomarkers on planetary surfaces is critical for the search for evidence of present or past life in our solar system. In our earlier instrument development efforts we addressed this need through the development of a near-infrared point spectrometer intended for quick-look examinations of samples that could be subsequently analyzed with a laser desorption time-of-flight mass spectrometer (LDTOF-MS) [1-3]. The point spectrometer utilized an acousto-optic tunable filter (AOTF) crystal as the wavelength selecting element [4]. In parallel with the aforementioned development efforts we identified the need for a portable version of the AOTF spectrometer that we could test and demonstrate in a range of field locations on Earth chosen to serve as terrestrial analogs for extreme environments elsewhere in the solar system. Here we describe the development and field testing of the Portable AOTF Spectrometer for Astrobiology (PASA).

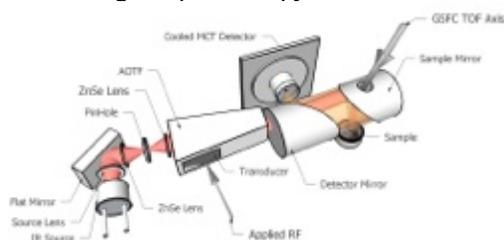
**Instrument Development:** The optical design of PASA is based on that of its predecessor, which we paired with an LDTOF-MS at NASA's Goddard Space Flight Center (GSFC) as part of an instrument suite in 2012 [1, 2]. The optical design and development of that spectrometer are described in detail in [4]. With the aim of portability in mind, PASA was designed to be more compact than its predecessor, and it also includes a context camera to provide optical imaging of the source to optimize its position in the field of view.

In brief, PASA consists of a detector element, an electronics module, an optics module, and a data acquisition system. Photons emitted from a broadband infrared light source are diffracted through the AOTF crystal, which acts as a spectral filter. The birefringent nature of the TeO<sub>2</sub> crystal coupled with an RF signal passed through the crystal diffracts the incident light through an aperture. The emergent narrowband light, whose wavelength is a function of the RF signal driven into the crystal, is then reflected off a sample mirror, focused onto a sample, reflected back to a detector mirror, and incident on a HgCdTe detector (Fig. 1). In this manner, the reflectance of the sample is measured as a function of wavelength, yielding an infrared

spectrum spanning 1.6–3.6 μm, with a spectral resolution ( $R = \lambda/\Delta\lambda$ ) of ~200-400.

**Field Sites:** Cave environments represent extreme environments on Earth where life is able to flourish despite a lack of sunlight. They also provide a stable thermal environment and refuge from harsh radiation exposure. Hence, in the context of solar system exploration they represent a reasonable location to investigate for evidence of extinct or extant life. We elected to test PASA in cave environments in order to exercise the instrument in extreme locations, as well as to characterize the effectiveness of NIR reflectance spectrometry as a tool for *in situ* biomarker detection.

We demonstrated PASA in two very different cave environments. The first field expedition, in October 2013, was to a predominantly gypsum and calcite cave in New Mexico (Fort Stanton Cave). The second field measurements were acquired in an actively forming cave rich in hydrated sulfates in Tabasco, Mexico (Cueva de Villa Luz) [5] in December 2013. Both of these microbially active environments contain evidence of biologic alteration of minerals, which can be detected using IR spectroscopy.



**Figure 1. Three dimensional schematic layout of PASA. An optical imaging camera was placed along the GSFC LDTOF-MS axis for context imaging.**

**Instrument Operations:** The optics and electronics modules and the data acquisition laptop are packaged and transported in three dessicated, sealed cases to reduce exposure to extreme environmental conditions (*e.g.* humidity). The entire system is powered by portable battery packs, which allow for several hours of continuous data acquisition. Figure 2 illustrates the instrument in use at Cueva de Villa Luz. The optics are housed in the grey rectangular box at left, which is held against a sample surface during data

acquisition. The general procedure for sample collection is to identify a region of interest, hook up the power and electronics cables, power on the data acquisition laptop, power on the instrument, allow time for the thermoelectric cooler to achieve operating temperature (~ 30 seconds) and acquire the data. Depending on the accessibility of our desired sample region, the entire process took between 15-30 minutes for each measurement.

**Resulting Data:** As an example of the data quality achievable with PASA, we present data for a “snottite” from Cueva de Villa Luz. Snottites (Fig. 3) are mucous-like stalactite features that are now known to be vertically suspended microbial colonies, similar to microbial mats that grow on rock surfaces near sulfur springs [5].

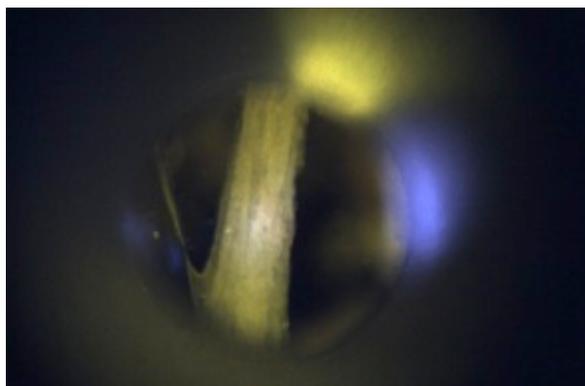
Figures 4 and 5 illustrate the PASA context image and near-IR spectrum of a snottite. To acquire these observations, PASA was oriented vertically so that the snottite dangled in front of the instrument aperture. Laboratory testing revealed that the instrument performance was the same regardless of the orientation of the instrument. The data shown in Fig. 5 represent an average of 256 scans across the complete spectral range of the instrument, which took approximately 30 seconds to complete



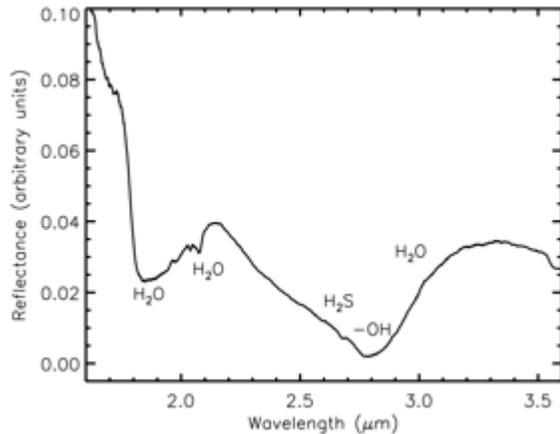
**Figure 2. PASA data acquisition in Cueva de Villa Luz in December 2013. Authors Chanover (left) and Uckert (right) are positioning the instrument and running the data acquisition software, respectively.**



**Figure 3. Photograph of a snottite in Cueva de Villa Luz.**



**Figure 4. PASA context camera image of a snottite in Cueva de Villa Luz.**



**Figure 5. PASA reflectance spectrum of the snottite shown in Fig. 4.**

In Fig. 5 we see absorption features corresponding to structurally bound H<sub>2</sub>O (2.7-3.5 μm), loosely bound H<sub>2</sub>O (1.85 and 2.1 μm), OH (2.79 μm), and possibly H<sub>2</sub>S (~ 2.6 μm). A detailed analysis of these data is still underway, but they suggest that near-IR reflectance spectroscopy is a promising technique for *in situ* characterization of cave surfaces and microbial colonies. The degree to which this technique can be used to infer the presence of biologic activity will be determined by its ability to detect evidence of minerals that are a result of biologic precipitation and/or crystal structure that is influenced by biologic activity.

**Conclusions:** We present the first field observations of cave environments using a portable reflectance spectrometer sensitive between 1.6-3.6 μm. We will present a more extensive suite of PASA spectra, along with their interpretation, in order to demonstrate its efficacy as a tool for biomarker detection on planetary surfaces.

**References:** [1] Chanover N. J. et al. (2013) *IEEE Aerospace Conference 2013*, 1–14. [2] Chanover N. J. et al. (2012) *International Workshop on Instrumentation for Planetary Missions*, Abstract #1683. [3] Uckert K., et al. (2014) *IEEE Aerospace Conference (2014)*, 1–12. [4] Tawalbeh R. et al. (2013) *Optical Engineering*, 52, 063604. [5] Hose, L. D. & Pisarowicz, J. A. (1999) *Journal of Cave and Karst Studies* 61(1), 13-21.

**Acknowledgements:** This work was supported by (1) NASA's EPSCoR program through grant number NNX12AK77A, (2) an Interdisciplinary Research Grant from the NMSU Vice President for Research, and (3) the National Geographic Society, which funded the expedition to Cueva de Villa Luz.