

The Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals

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Introduction: The Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) is a robotic arm-mounted instrument on NASA's *Perseverance* rover [1-2] (**Fig. 1**). SHERLOC has two primary boresights. The Spectroscopy boresight generates spatially resolved chemical maps using fluorescence and Raman spectroscopy coupled to microscopic images for texture and context (10.1 $\mu\text{m}/\text{pixel}$). The second boresight is a Wide Angle Topographic Sensor for Operations and eNgeineering (WATSON); a copy of the Mars Science Laboratory (MSL) Mars Hand Lens Imager (MAHLI) that obtains color images from microscopic scales ($\sim 13 \mu\text{m}/\text{pixel}$) to infinity [3]. In addition to the two detection boresights, the SHERLOC Calibration Target (SCT) provides a means to spectrally calibrate, spatially calibrate the mapping and imaging, and enables system sensitivity assessment. The SCT also includes an experiment for future human exploration that uses the deep fluorescence/Raman and imaging to assess spacesuit textiles resistance to the Martian environment [4].

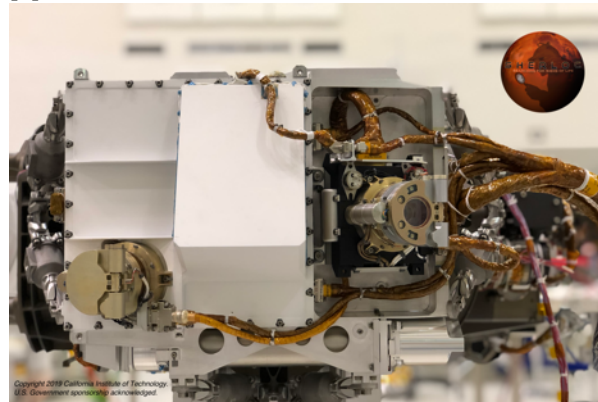


Fig 1. SHERLOC flight model. The left is the spectroscopy boresight with the cover closed, and on the right is the WATSON boresight with its transparent window.

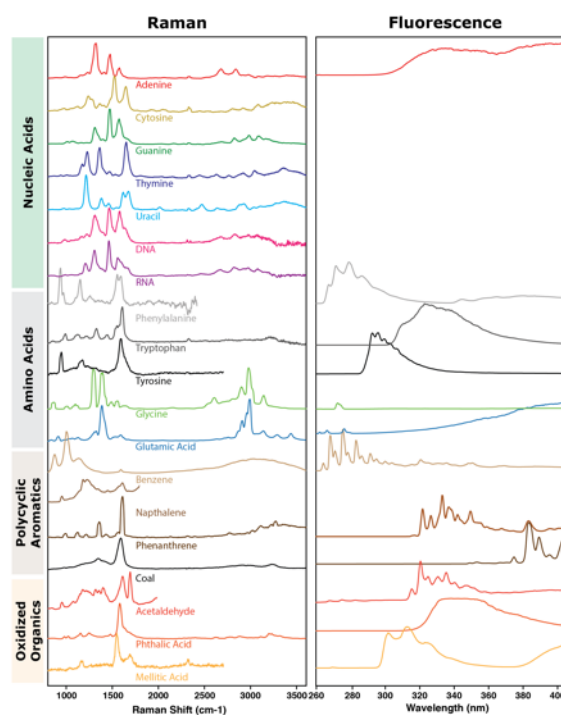


Fig 2. Example deep UV fluorescence and Raman spectra of various classes of organic detectable by SHERLOC.

SHERLOC Spectroscopy: SHERLOC fuses two spectroscopic methods together, deep UV fluorescence and deep UV Raman to detect organics and minerals and spatially resolve their distributions and to spatially correlate to determine their provenance (**Fig 2**). This combined spectroscopic mapping method is enabled by scanning >1000 positions over a $7 \times 7 \text{ mm}$ surface area with narrow-line (4GHz) 248.6 nm deep UV NeCu laser where each position generates spectrum using a single diffractive grating spectrograph over a spectral range of 250 to $\sim 370 \text{ nm}$. The Raman region from $\sim 800 - 4000 \text{ cm}^{-1}$ (250 to 273 nm) is spectrally separated from the fluorescence region (274 to $\sim 370 \text{ nm}$) but are acquired

simultaneously without time gating or additional mechanisms.

Deep UV fluorescence is uniquely sensitive to compounds incorporate aromatic ring structures. In simple terms, fluorescence provides insight on the electronic states of a molecule. It requires that a molecule absorbs an incident photon such that a bound electron can jump from a ground state to an excited one. The energy loss upon its return to ground, within 100's of picoseconds, provides information about the available energy levels; the smaller the gap, the longer the wavelength, the larger the aromatic compound. We previously demonstrated that the fluorescence, when excited < 250 nm, the detection of and differentiability of organics is enhanced and has led to rapid detection of trace organics with picogram sensitivities [5-6]. However, the organics differentiability is limited by the broad spectral features of fluorescence and the deep UV Raman spectrum adds higher levels of differentiability and enhanced sensitivity to aromatic amino acids, nucleic acids, heterocycles and polyaromatic hydrocarbons, PAHs, as well as aliphatic molecules [7-10]. However, to obtain the Raman, longer duration analyses (more laser pulses per scanning position) is required. Therefore, SHERLOC targets the deep UV Raman analysis of organics using the fluorescence scans to locate organics "hotspots".

In addition to organic analysis the deep UV Raman also provides mineralogic features to provide context to detected organics and general mineralogy of the surface [9, 11]. However, a current technological limitation in optical filters attenuate the Raman signals below ~800 cm⁻¹ such that many mineral oxides are not observed [11].

SHERLOC Operations (Fig. 3): SHERLOC operations begins by using an Autofocus Context Imager (ACI) to focus onto a surface (natural or abraded) and acquire 10.1 μm/pixel greyscale images. Chemical maps of organic and mineral signatures are acquired by the orchestration of an internal scanning mirror that moves the focused laser spot across discrete points on the target surface where spectra are captured on the spectrometer detector. ACI images and chemical maps (< 100 μm/mapping pixel) will enable the first Mars *in situ* view of the spatial distribution and interaction between organics, minerals, and chemicals important to the assessment of potential biogenicity (containing CHNOPS). Using different arm placements, imaging mosaics and chemical maps can be generated that cover the majority of a 45 mm diameter abraded surface mm. This microscopic view of the organic geochemistry of a target at the *Perseverance* field site, when combined with the other instruments, PIXL and SuperCam, will enable unprecedented analysis of

geological materials for both scientific research and determination of which samples to collect and cache for Mars sample return.

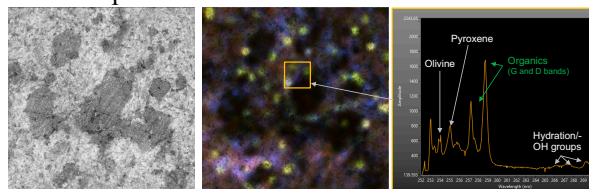


Fig 3. Example of a SHERLOC "survey" using the Sayh al Uhaymir 008 (SaU 008) Mars meteorite. The acquisition begins with a high resolution (10.1 μm/pixel) visible greyscale context image (left), followed a deep UV fluorescence map over the 7x7 mm area (center). From this data a Raman spectra can be extracted from a 1x1 mm the map of "hotspots" showing the mineralogy and presence of organics. This data was collected using the SHERLOC flight model in instrument system thermal testing.

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