LABORATORY-BASED UV REFLECTANCE SPECTROSCOPY IN SUPPORT OF MARS 2020 RETURNED SAMPLE SCIENCE. Monica M. Grady[1,2], C. Batty[1], S. Farsang[1,3] and P. Rowden[1], [1]School of Physical Sciences, Open University, Milton Keynes MK76AA, UK (monica.grady@open.ac.uk); [2]Dept. Earth Sciences, The Natural History Museum, London, UK; [3]Dept. Earth Sciences, Univ. Cambridge, Cambridge, UK;

Introduction: Reflectance spectroscopy over a range of wavelengths is a common tool used to determine the composition and mineralogy of planetary surfaces. It has been used extensively and successfully at Mars to map regions of significant aqueous activity. Most observations have been in the Vis-NIR (~ 300 – 2100 nm). Hydrous and anhydrous silicate minerals, sulphides, sulphates and carbonates all have prominent features within this range. Organic species are detectable at lower wavelengths, down into the ultraviolet (UV), from ~ 180 – 300 nm, but few measurements have been taken of planetary surfaces in this wavelength range. This will change with Mars-2020: the Sherloc instrument will acquire spectroscopic data from surface materials and core-hole interiors over the wavelength range from 250 – 410 nm, enabling detection and identification of organic and mineral species from a combination of Raman and fluorescence spectroscopy [1].

Amongst the questions that the Mars-2020 Science Team will be considering as they prepare for deployment of the rover on Mars' surface are those concerning the materials they will encounter. One of the most significant issues surrounds the sort of samples that should be collected and returned to Earth to enable a greater understanding of the evolution of Mars and its potential for habitability.

The purpose of this study is to investigate mineral-organic relationships in martian meteorites using the technique of UV microspectrophotometry. The idea is to produce spatial distributions of organic species on broken surfaces of meteorites and terrestrial analogues. The work will have synergies with the type of investigation that the Sherloc instrument will be carrying out on the surface of Mars. The aim is to provide an additional series of analyses that could assist in interpretation of data acquired on Mars. That would then help in identifying suitable (potentially organic-rich) rocks for acquisition and caching.

The research will impact on our state of knowledge of mineral-organic assemblages on the surface of Mars, and has the potential to supply information critical to identification of biosignatures in rocks returned from Mars. We know through careful analysis of data acquired from orbit and by instruments on the Curiosity and Spirit rovers that there are outcrops of rocks – lacustrine or hydrothermally-altered – where minerals produced by the action of fluids are abundant [e.g., 2, 3]. By analogy with terrestrial strata, we know that such rocks are frequently the habitats of micro-organisms, and so they are prime targets for investigation on Mars, and potential subsequent collection for return to Earth [4].

In contrast to IR spectra, which are produced by bending and stretching of bonds between atoms, UV-VIS spectra (200 – 800 nm) are generated by electronic transitions within atoms and molecules. Electrons move between energy levels, emitting or absorbing energy as they do so. UV spectra are not as diagnostic as IR or Raman spectra for precise identification of species (mineral or organic). Nonetheless, UV spectroscopy is a valuable complement to other types of spectroscopy, partly because it is a rapid, non-invasive and non-destructive technique that requires no sample preparation, and partly because species that do not produce IR spectra (e.g., homonuclear molecules) are usually UV-active.

Method: Diffuse reflectance spectra of a series of powdered organic compounds and carbonaceous chondrites were obtained using a CRAIC UV-Vis micro-spectrophotometer (MSP) fitted with 3 Cassegrain objective lenses [5]. The MSP has two separate light sources (deuterium and xenon lamps) that can be operated in parallel, giving a useful spectral range of 200 – 900 nm (limited by the sensitivity of the installed solid state detector). The combined output from the two lamps is delivered to the microscope by fibre optic, where it is focusable through the microscope to an area between 10 x 10 µm down to 2 x 2 µm in size depending on the combination of mirrors selected. Viewing geometry is such that incidence and exit angles of the light are perpendicular to the sample. The technique is complementary with methods that analyse finely-ground homogenized powders, as we are able to obtain spectra from either powdered materials or thin sections, as long as the grains at least fill the 2 x 2 µm field of view.

Results: We report here the UV spectra (240 – 400 nm) of a series of inorganic minerals relevant to the composition of Mars' surface. Using the same experimental protocol, we have also measured the 240 – 400 nm spectra of the Nakhla and Zagami martian meteorites. (Figure 1). The spectra are normalized to the Spectralon^{TM} white standard. As reported in a companion abstract [6], we have also measured the UV spectra of a series of organic species (Figure 2). The maxima at 285 nm and 324 nm shown in Figure 2 are clearly associated with an organic functional group, even if its identity is not yet known [6]. The same features are also present in the martian meteorites but not the inorganic minerals. It is possible that the features in Nakhla and Zagami are terrestrial contaminants – but they are specimens that have been curated and processed under clean-room conditions. The minerals came from a collection that had not been curated in clean-room conditions, and so might be expected to demonstrate organic compounds from contaminants.

Grady et al [6] inferred that the 324 nm feature could be associated with the abundant macromolecular material contained within carbonaceous chondrites. If so, it might also be recording the presence of a similar species in the martian meteorites; complex organics have been detected in martian meteorites by Raman spectroscopy [7] and stepped combustion mass spectrometry [8]

Conclusions: UV spectroscopy is a potential tool for the rapid, non-invasive and non-destructive analysis of planetary samples. Comparison with spectra from organic and inorganic species should allow elucidation of interactions between organics and mineral matrices, and assist in interpretation of data from the surface of Mars.

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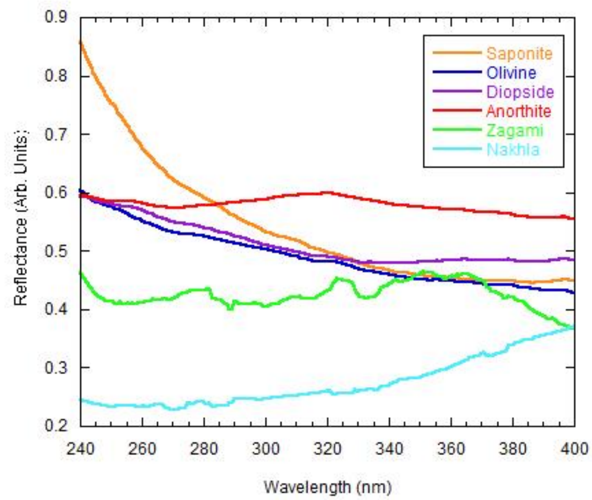

Figure 1: UV reflectance spectra of the Nakhla and Zagami martian meteorites, alongside spectra from a suite of minerals relevant to the martian surface.

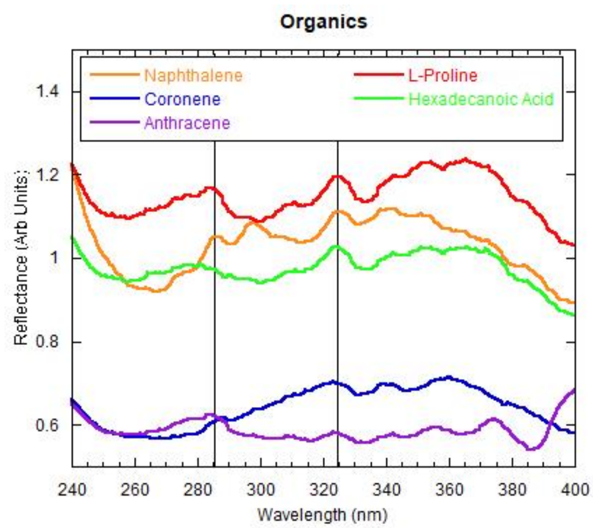

Figure 2: Reflectance spectra of three unsaturated aromatic compounds (naphthalene, anthracene and coronene), a monocarboxylic acid (hexadecenoic acid ($C_{16}H_{32}O_2$) and an amino acid (L-Proline, $C_5H_9NO_2$). Features at 285 nm and 324 nm are marked for comparison across the organic species and with the meteorites.