

IDENTIFICATION OF ORGANIC COMPONENTS IN CARBONACEOUS CHONDRITES BY UV SPECTROSCOPY. Monica M. Grady^{1,2}, C. Batty¹, S. Farsang^{1,3} and P. Rowden¹, ¹School of Physical Sciences, Open University, Milton Keynes MK76AA, UK (monica.grady@open.ac.uk); ²Dept. Earth Sciences, The Natural History Museum, London, UK; ³Dept. Earth Sciences, Univ. Cambridge, Cambridge, UK;

Introduction: VIS-NIR reflectance spectroscopy (wavelength range ~ 300 – 1500 nm) is an important technique in planetary exploration: the major groups of silicate minerals have characteristic features in this spectral range, enabling data from instrumentation on-board spacecraft to be compared with equivalent information from laboratory analysis to determine the mineralogy of planetary surfaces. Classification of asteroid families, matching spectra to those of meteorites has enabled identification of parental sources for the meteorites, e.g., Vesta as the source of HED [1].

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 molecule. Electrons move between energy levels, emitting or absorbing energy as they do so. At the UV end of the spectrum, organic species exhibit features that are related to bond geometry, depending on whether the bonds between carbon atoms are single, double or triple. The structure of the molecule is also important (aliphatic chain or aromatic ring), as is its conjugation (number of atoms or rings, the presence of functional groups). Unfortunately, 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.

Given the continuing interest in organic species within the Solar System, we are starting to build a library of UV spectra from a range of organic compounds and minerals, as well as from meteorites. This will enable us to compare UV spectra from planetary surfaces with analogous spectra from meteorites and other materials, in order to determine the distribution and identity of organics within the Solar System. Previous contributions in this field [e.g., 2-4] have mainly used bulk methods to obtain spectra; we are using microspectrophotometry, whereby the incident light beam is focused onto a small area of sample. Our aim, eventually, is to enable the technique to be extended to individual particles of cometary or asteroidal dust.

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 organic species (Figure 1) analogous to those identified in carbonaceous chondrites by gas chromatography. The spectra are normalized to the SpectralonTM white standard. Marked in the figures are maxima at 285 nm and 324 nm; the former is related to the carbonyl group (R-CO-R', where R and R' are saturated functional groups). The maximum at 324 nm is also related to a carbonyl group, but in this case either R or R' is an unsaturated functional group. Figure 1 shows that the three aromatic hydrocarbons naphthalene (2 rings; linear; C₁₀H₈), anthracene (3 rings; linear; C₁₄H₁₀) and coronene (6 rings; cyclic; C₂₄H₁₂) also have features around 285 nm and 324 nm, and none of these compounds has a carbonyl group. In this case, the features result from transitions of the delocalized electrons associated with the C to C bonds. It is apparent from this very brief analysis of the UV spectra of a limited number of pure organic compounds that there is considerable overlap in the spectral ranges of features associated with different functional groups. In order to distinguish more successfully between functional groups, we will extend our analysis to longer wavelengths.

Using the same experimental protocol, we have also measured the 240 – 400 nm spectra of 5 carbonaceous chondrites (Alais, Orgueil, Tagish Lake, Murchison and Cold Bokkeveld; Figure 2). Maxima at 285 nm and 324 nm are again marked for comparison with the organic compounds. All five of the chondrites exhibit the band at 324 nm. One possible inference that could

be drawn is that the feature is associated with the abundant macromolecular material contained within carbonaceous chondrites. This is a highly undersaturated complex containing cross-linked aromatic rings, and might be expected to have spectral similarities to aromatic molecules. In contrast, the 285 nm band occurs as a shallow doublet in Orgueil, Cold Bokkeveld and Tagish Lake, whilst it is offset to lower wavelengths in Alais and Murchison.

Conclusions: UV spectroscopy is a useful technique for the recognition of the presence of carbonaceous phases on a planetary surface [6]. However, before we can establish it as a useful tool for the identification of individual organic species within a complex mixture of organic molecules, a more detailed library of spectra from appropriate species must be constructed. Even so, a first pass at comparison of organic molecules with carbonaceous chondrites has shown differences between the organic constituents of the meteorites. One of our next steps will be to look again at UV spectral data from asteroids [7], again for comparison with the chondrite data.

References: [1] Binzel R. P. and Xu S. (1993). *Science* 260, 186-191; [2] Wagner J. K. et al. (1987). *Icarus* 69, 14-28; [3] Cloutis E. et al. (2011). *Icarus* 212, 180-209; [4] Appin D. et al. (2018). *Icarus* 307, 40-82 [5] Fernandes C. D. et al. 2001. *Int. J. Astrobiol.* 5, 287; [6] Hendrix A. R. (2016). *MAPS* 51, 105-115; [7] Roettger E. E. and Burrati B. J. (1994). *Icarus* 112, 496-512.

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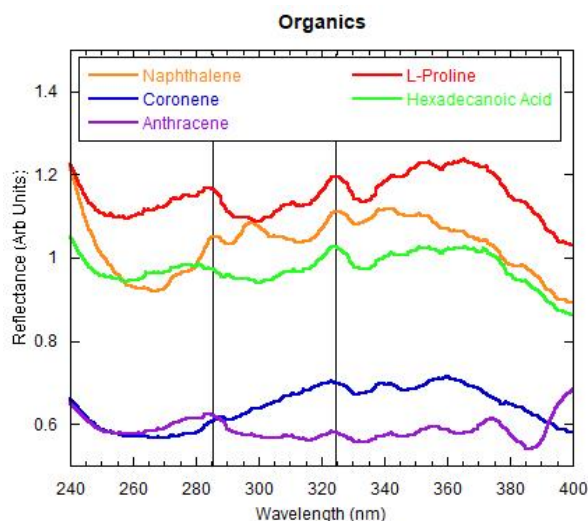


Figure 1: Reflectance spectra of three unsaturated aromatic compounds (naphthalene, anthracene and coronene), a monocarboxylic acid (hexadecanoic acid ($C_{16}H_{32}O_2$)) and an amino acid (L-Proline, $C_5H_9NO_2$). Features at 285 nm and 324 nm are marked for comparison across the organic species and with the meteorites.

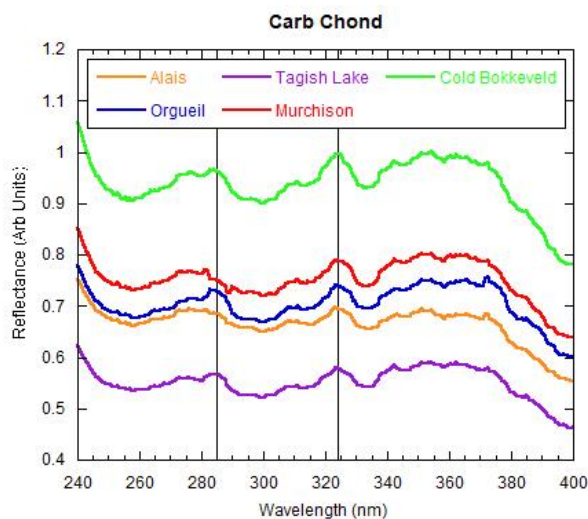


Figure 2: Reflectance spectra of five carbonaceous chondrites: Alais and Orgueil (CI1), Tagish Lake (CI2/CM1?), Murchison and Cold Bokkeveld (CM2). Features at 285 nm and 324 nm are marked for comparison across the meteorites and with the organic species.