A miniature UV-VIS spectrometer for the surface of Mars

Conference or Workshop Item

A MINIATURE UV-VIS SPECTROMETER FOR THE SURFACE OF MARS . M.R. Patel[1], M.C. Towner[1], J.C. Zarnecki[1], M.R. Leese[1], A. Davies[2] and A. Husbands[2], [1]PSSRI, The Open University, Walton Hall, Milton Keynes, MK7 6AA, U.K., email: m.r.patel@open.ac.uk, [2]Anglia Instruments Ltd., PO Box 147, Soham, Ely, Cambridgeshire, CB7 5QL, U.K.

Introduction: A miniature spectrometer (~100 g) is in the process of development for future surface missions to Mars, aimed at measuring the UV-VIS spectrum encountered at the martian surface. Responsivity of the unit covers the wavelength range 200-800 nm, with a resolution of 1.5 nm. Great uncertainty lies in the derivation of optical properties of suspended dust in the martian atmosphere at UV wavelengths required for accurate modelling of the transfer of UV to the surface. This instrument will provide surface spectra ranging from the UV to visible, thus allowing the derivation of optical properties across a wide region of wavelength. Presented here are initial results from laboratory experiments, verifying the concept of the spectrometer for its development as part of the ExoMars mission to Mars.

General Spectrometry: The study of solar spectral irradiance from planetary surfaces is important in a wide range of disciplines. Solar irradiance is a key input parameter for atmospheric modelling, and governs the photochemistry of planetary atmospheres. UV and visible radiation are also important in the case of astrobiology – visible light is required for photosynthesis, but short wavelength UV can be extremely damaging to biological structures, in some cases placing a limitation on the viability of micro-organisms.

In the case of Mars, measurements of solar irradiance as a function of wavelength have often been taken from orbit on numerous occasions (see [1] and references therein), and have always been incorporated into the imaging systems of planetary landers through the use of narrow band filters (e.g. [2], [3]). High resolution *in situ* spectroscopic measurements however have never been obtained, and remain an important measurement to describe accurately the electromagnetic spectrum encountered at the martian surface.

Martian UV Spectra: The presence of ubiquitous dust suspended in the martian atmosphere introduces a complex and highly variable element into theoretical simulations of surface fluxes. In martian radiative transfer simulations, two optical properties of the suspended dust need to be known – the single scattering albedo (w_{bd}) and the asymmetry parameter (g_{bd}). Due to the lack of *in situ* spectral measurements from the surface the nature of these optical properties still remains highly debated, and needs to be resolved to model accurately the UV region of the spectrum at the martian surface. This contrasts the visible region, where many previous measurements of surface irradiance have been taken, and agreement is seen between different observations in the visible.

Using the optical properties for martian dust as derived by [4], the UV spectrum encountered at the martian surface was simulated, shown in Figure 1. The model is a multi-layer atmospheric model, using the delta-Eddington approximation for radiative transfer flux. This model is described in detail in [1] and [5], and the description of the model is omitted here.

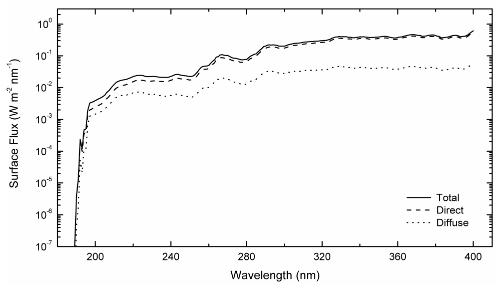

Figure 1: Martian surface UV spectrum.

The contribution from scattering events with dust particles creates the diffuse irradiance, which is always present in all martian spectra. Another important modifier of the UV spectrum is O_3. O_3 is a seasonally and geographically variable constituent of the martian atmosphere, with peak absorption in the UV near 250 nm. Peak abundances tend to occur at high latitudes at northern winter, decreasing towards summer [6]. Given high enough O_3 abundances, an absorption band should in theory be observed in martian surface UV spectra.

A UV-VIS Spectrometer for Mars: Advances in optical technologies have drastically reduced the mass, power and volume requirements for spectrometers to extremely small levels. Such developments lead to the conclusion that with further engineering, the current technology could in theory be included in the payload for future missions to the martian surface.

The unit under consideration here is the AvaSpec Spectrometer, manufactured by Avantes and supplied by Anglia Instruments UK. The spectrometer incorporates a 2048-element linear CCD array, and an optical bench with a focal length of only 75 mm. This family of spectrometers cover the range 200-1100 nm, with a resolution of up to 0.1 nm dependent upon configuration choice.

The dimensions of the unit are 175×110×44 mm, with a power consumption of only 1.92 W. The majority of this power consumption occurs in the processing electronics for the USB and RS-232 interfaces, and could be significantly reduced if removed. The optical bench is based upon a symmetrical Czerny-Turner design, shown in Figure 2. The detection range and resolution are set by the choice of diffraction grating.

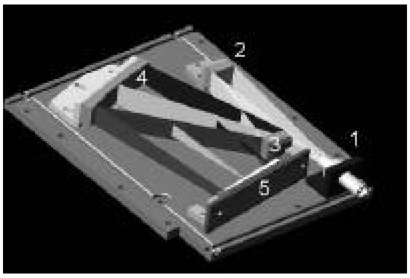

Figure 2: Optical bench design of the AvaSpec 2048. (Key: 1 - Fibre optic input. 2 - Collimating mirror. 3 - Diffraction grating. 4 - Collimating mirror. 5 - CCD array).

Ruggedisation of the optical bench will drastically reduce the mass to an anticipated ~100 g. The fibre optic input interface also allows the optical bench to be housed anywhere within the lander structure, with the fibre optic cable supplying the detected light from a suitable location on the lander.

The development of this unit to space qualified standards will be undertaken through a collaborative agreement between the Planetary and Space Sciences Research Institute (PSSRI) and Anglia Instruments UK. The optical bench will be ruggedised and reduced in mass, and the electronics will be replaced with a qualified interface for integration onto a planetary lander. Currently the spectrometer has a detection range of 200-800 nm, with a resolution of 1.5 nm. A higher resolution can be achieved by selecting a smaller wavelength detection range. The unit will form part of a payload proposal for the ExoMars mission in 2009, offering high resolution spectrometry directly from the surface of Mars for the first time, and requiring a mass allocation of only 100 g.

Preliminary Results: The preliminary results from exposure to a UV-VIS source are shown here. A Xenon light source was used to irradiate the spectrometer, across the full 200-800 nm range, to determine the quality of the wide band response. The response of the unit to the source is shown in Figure 3. The response of the spectrometer is clearly defined, showing detailed structures and a distinct output curve. The full spectrum is covered, giving good coverage over all the available areas. The irradiance at 200 nm is extremely low, since the Xenon output at this wavelength is far lower with respect to the visible region. This test however clearly demonstrates that the unit is viable for application on a planetary mission, given its extremely low mass and power consumption.

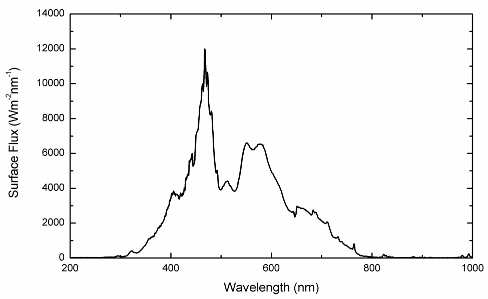

Figure 3: AvaSpec 2048 response to Xenon lamp.

As well as the evaluation of dust optical properties in the martian atmosphere, this spectrometer will also in theory allow the detection of O_3 in the martian atmosphere. The presence of O_3 creates a 'dip' in the observed spectrum, which though comparison with model can yield the column abundance of O_3. Given a high enough signal to noise ratio, the detection of O_3 should be possible.

Summary: The problems remaining in the optical properties of martian dust at UV wavelengths has been shown, and a need for high resolution spectrometry exists on future surface missions to Mars. High resolution *in situ* surface spectral data will help us understand better the biologically relevant UV radiation that is present at the martian surface, and the subsequent implications for astrobiology. Accurate data on the scattering and absorption properties of martian dust will help refine future and existing radiative transfer models, which can then be used to investigate further various UV environmental conditions. The instrument which could fulfill this requirement on the ExoMars mission is currently under development, and will offer an invaluable insight into the martian UV-VIS environment and answer the current question of the UV optical properties of suspended martian dust, for a mass of only 100 g.

References: [1] Patel, M.R. et al (2002). *Planet. Space Sci.* **50** (9), 915-927. [2] Pollack, J.B. et al (1977) *JGR* **82** (28), 4479-4496. [3] Smith, P.H., et al. (1997) *Science* **278**, 1758-1764. [4] Ockert-Bell, M.E. et al (1997) *JGR*, **102** (E4), 9039-9050. [5] Patel, M.R. et al (2003) *Int. J. Astrobiology* **2** (1), 21-34. [6] Barth, C.A. et al (1973) *Science* **179**, 795-796.