Habitability of the Martian Subsurface: A UV Perspective. C. A. Moore[1], C. L. Smith[2], and J. E. Moores[3] [1] York University, 4700 Keele Street, Toronto, ON, M3J 1P3, moore.casey@gmail.com, [2] York University, 4700 Keele Street, Toronto, ON, M3J 1P3, chrsmith@yorku.ca, [3] York University, 4700 Keele Street, Toronto, ON, M3J 1P3, jmoores@yorku.ca

Introduction: Studies of the transmissive properties of martian regolith and rock analogs [1-3] typically report on the transmission of radiation perpendicular to the surface. These measurements do not fully characterize the amount of transmission into the samples as they exclude any scattering that may redirect light into other phase angles. This has the effect of underestimating the amount of light propagating through the sample via multiple surface scattering.

This study examines experimental results of the transmitting scattering phase function through martian surface analogs in an attempt to better model radiative transfer in the martian subsurface environment. We then propose a theoretical exercise to identify the depths at which terrestrial radioresistant organisms could survive in the martian subsurface environment with regards to ultraviolet radiation. It should be noted that this exercise does not take into account other environmental factors such as temperature and pressure cycling, atmospheric composition, and other forms of harmful radiation that make it to the martian surface.

Methods: A mini-goniometer was built to characterize the transmittance of radiation through martian regolith and rock analogs as a function of wavelength and scattering angle. These transmission spectroscopy measurements were taken for substrates including granular basalt, cheto bentonite, calcite, kieserite and JSC Mars-1 [4]; and thin slices of impact generated crystalline rocks from the high arctic [3]. Samples of JSC Mars-1, a very popular martian regolith analog, tend to show a strong forward transmission profile, which would be adequately estimated using the aforementioned typical perpendicular transmission measurement. Not all samples exhibit this forward transmission, however, as kieserite and the set of impact generated crystalline rock samples typically show a more isotropic transmission scattering phase function, with near uniform transmission with scattering angle for the angles accessible with the mini-goniometer. In similar materials, the use of only the perpendicular transmission would drastically underestimate the amount of radiation propagating through the samples.

The transmission spectroscopy for martian analog materials is assessed at two sample thicknesses, allowing a model of the transmittance as a function of depth to be made; as in Figure 1 which shows transmission

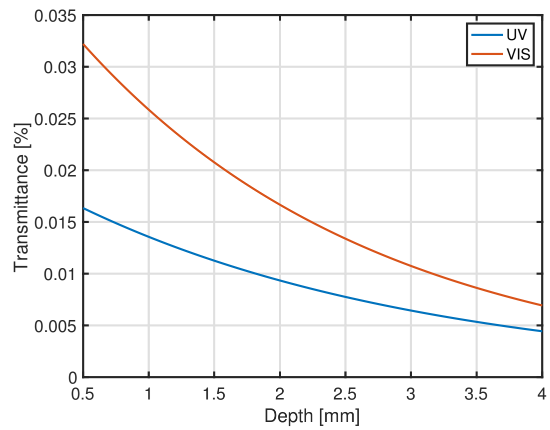

Figure 1: Modelled UV (280 - 400 nm) and visible (400 - 700 nm) transmission with depth into a granular kieserite substrate, derived from transmission spectroscopy at varying sample thicknesses.

of UV and visible wavelengths as a function of depth into a granular kieserite substrate. Here we see that the UV wavelengths are attenuated more than their visible counterparts suggesting that this material effectively shields harmful UV radiation and potentially allows visible wavelengths to act as a source of energy at these depths. This was seen in several of the samples to varying degrees.

We combine the transmission profile with martian insolation values, which are taken from the literature [5,6] to model the radiation environment of the samples under martian conditions. The modelled insolation comes from a doubling and adding radiative transfer code [7] and are reported as the zonal mean longitudinal insolation as a function of season.

The lethal dose of UV radiation to eliminate 90% of a population (LD_{90}) of *Bacillus subtilis* and Tardigrades are taken from the literature [8-9], 28 kJ m^{-2} and 74 kJ m^{-2}, respectively. For comparison, 0.08 kJ m^{-2} is enough dosage to inactivate most bacteria and viruses commonly found in drinking water.

The model assumes that the radioresistant organisms can withstand LD_{90} levels of radiation on a per sol (martian day) basis. This value is chosen as we would expect that extant species on Mars would have adapted to the harsh radiation environment of Mars.

Results: Depths between 2 and 10 mm into the martian surface are required to sufficiently shield UV radiation to levels deemed survivable for *B. subtilis* and tardigrades depending on substrate used and martian season (Figure 2; for tardigrades in a kieserite substrate). This leads to the possibility of finding biosignatures from extant or extinct lifeforms within martian bedforms and endolithic environments, assuming the lifeforms have adapted to the other extreme conditions of the martian environment.

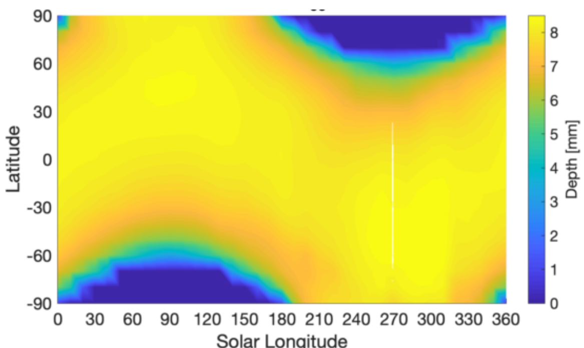

Figure 2: Modelled depth at which LD_{90} occurs for tardigrades in a kieserite substrate utilizing zonal mean longitudinal martian insolation values as a function of solar longitude.

The model also suggests that during martian winters, e.g. solar longitudes (Ls) of 0 – 180° and Ls = 180 – 360° for the southern and northern hemisphere, respectively, the martian surface is habitable with regards to UV radiation. This is due to the tilt of Mars, which, like Earth, causes months of night in the winter polar regions, and thus zero insolation from the Sun. From a strictly UV perspective, the martian polar regions could be habitable for lifeforms for extended periods of time, so long as they do not require radiation as an energy source and have evolved to be hardened against other martian environmental factors.

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