INVESTIGATING THE VIABILITY OF BACTERIAL SPORES UNDER NEAR-SURFACE CONDITIONS OF ICY WORLDS

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Introduction: The icy worlds Europa and Enceladus are leading astrobiological targets because of the likelihood that they both contain a subsurface ocean in contact with a rocky interior allowing for hydrothermal activity and the necessary conditions for life [1-3]. In addition, both worlds show clear evidence for surface-subsurface interaction via plumes, ice shell tectonics, and chaos regions; so any life in the ocean may find its way to the surface. Short of direct plume capture, the near-surface (< 1 meter depth) provides the best chance of a mission assessing any evidence for extant life, because of the difficulty of drilling deeper into the ice shells at this point in time.

The near-surface conditions at both Europa and Enceladus are hostile to life as we know it, primarily due to the UVB,C irradiation, but at Europa also due to the large particle fluxes. However, each also contains chemical species at the surface which can potentially provide some amount of shielding from the incoming irradiation at depths of only mm – cms. Therefore, it is important to determine in the lab the viability of microorganisms, and photochemical pathways of important biomolecules, under these relevant near-surface conditions to identify high quality targets for life detection missions.

Bacillus subtilis spores are a useful model organism for investigating the effects of irradiation under icy world conditions because of their relatively high resistance to a wide variety of extreme conditions in space [4]. Furthermore, the survival of microorganisms at the surface of icy worlds is also critical for establishing planetary protection requirements of future icy worlds missions, so establishing the ability of spores to survive after deposition could also inform those requirements.

Previous Work: In our initial work [5], *B. subtilis* spores and one of their major biochemical components, dipicolinic acid (DPA) were each irradiated in a high vacuum chamber at temperatures relevant to Europa and Enceladus. Spectra of both were taken with FTIR pre- and post-irradiation to observe photochemical changes after different amounts of irradiation. Spores were recovered and cultured to measure changes in the rate of UV inactivation between 100K and room temperature. Irradiation experiments were also performed with micron layers of ice cover to explore the importance of shielding VUV photons as well as the role of hydroxyl radicals in inactivating spores.

The UV photolysis pathway of DPA was found to include the same novel photoproducts as those observed in the spectra of irradiated spores confirming the importance of DPA as a spectral marker of spores and as a part of their UV resistance.

Spores remained viable under UV irradiation longer at 100 K than at room temperature in agreement with previous work [6, 7]. Ice layers covering the spores did not change their photochemistry or reduction in viability compared to uncovered spores.

This work began to constrain the ability of microbes to survive under Europan conditions, and observed a 99.9% reduction in *B. subtilis* viability after ~40 hrs of irradiation at Europa.

Experimental Plan and Initial Results:

More work is needed to explore the potential for species in the ice to extend the viability of organisms at the surface by shielding them from radiation. Therefore, we are studying the ability of SO_2, H_2O_2, NH_3, $MgSO_4$, and $NaHCO_3$ in ice matrices to enhance spore survival under UV or electron irradiation. There is also evidence that spore survival may increase dramatically at even lower temperatures. We will investigate by exploring the temperature range between 30 and 100K to determine if high lattitudes might be especially suitable for preserving microorganisms.

Our initial results presented here will focus on the addition of SO_2 doped into ice layers and its affect on the viability of spores after UVB,C irradiation as well as the the effect of similar irradiation at temperatures as low as 30K.

References:

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