VIABILITY OF BACTERIAL SPORES UNDER ICY WORLD SURFACE CONDITIONS.

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Introduction: Sub-surface oceans of icy worlds like Enceladus and Europa are some of the most likely places to arbor non-Earth life in our Solar System. Microorganisms could have formed and develop at the warm seafloor and parts might possibly migrate to the icy surface via plumes or cryovolcanism.

Laboratory studies to understand microorganism viability under the harsh conditions encountered on icy world surfaces are needed to support microbial detection efforts associated with an eventual landed mission. Such studies are also needed for planetary protection purposes to estimate the risk of contamination by terrestrial life of outer Solar System landing targets.

Methods: We present experimental results on the viability of *Bacillus Subtilis* spores, a resilient microorganism used to assess sterilization procedures on Earth. Here, its viability is assed under conditions similar to that found at the surface of icy worlds: low temperature, vacuum, ice, and UV/electron irradiation. The bacterial spores are deposited onto coupons [1] placed inside a vacuum chamber and cooled to temperatures as low at 10K. Ices can be deposited onto the spores by injecting pure or mixed vapor onto the cryocooled coupons. A UV lamp mimicking the sun spectrum or an electron gun in the keV range is used to irradiated the bacterial spores during various amount of time (Figure 1). Viability is then assessed by retrieving the coupons, culturing the irradiated spores, and comparing the number of colony-forming units to controls.

Results: We explored the inactivation kinetics by UV photons and electrons for various temperatures relevant to icy-ocean world surfaces (Figure 2). In the case of UV irradiation, the inactivation exponentially decreases with temperature but is leveling off under 60K, which is likely due to complex DNA inactivation/repair mechanism. From this kinetic quantification, we expect Bacillus subtilis spores to be deactivated on sub-hour timescales at the top surface of Europa and Enceladus, taking into account their distance to the Sun and average surface temperature [2,3].

For the case of electron irradiation, inactivation kinetics are measured for water ice-covered spores to take into account the balance between ice shielding and inactivation by secondary particles. We can thus provide an estimation of the spore survival rate with ice depth on icy worlds.

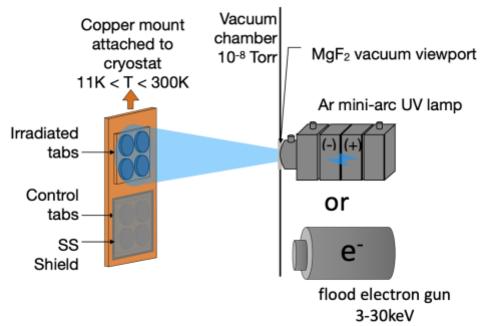

Figure 1 Cartoon of the experimental setup used for irradiating the Bacillus subtilis spore at cryogenic temperatures under vacuum.

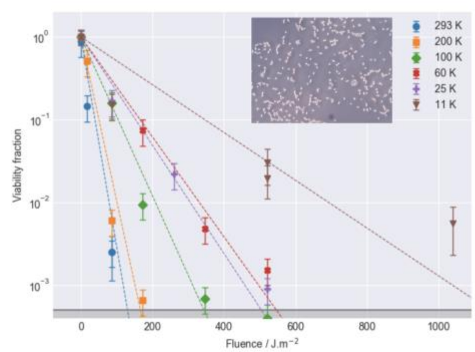

Figure 2 Viability fraction of *B. subtilis* spores under UV irradiation versus UV fluence for various temperatures and a phase contrast microscopy image of a spore submonolayer deposited onto a glass slide, using a similar technique when performing irradiations.

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References:

[1] Noell A. C. et al. (2013) *J. Microbiol. Methods 94,* 245. [2] Noell A. C. et al. (2015) *Astrobiology 15,* 20. [3] Fayolle E. C. et al. (2020) *Astrobiology 20,* 889.