BACTERIAL CONCENTRATION IN BUBBLES BURSTING UNDER VACUUM.

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Introduction: The Cassini mission provided compelling evidence that Saturn's moon Enceladus possesses all of the required ingredients for life: a subsurface liquid ocean, a source of heat (geothermal), and all chemical building blocks (with the possible exception of phosphorus) (*1*). Enceladus has thus become a major target for astrobiology mission design studies (*2*) (*3*). Because of the low escape velocity of this moon (207 m/s) and the icy plumes that escape from its surface, a flyby mission to capture plume material is a viable approach (*4*) or a lander could collect ice grains that were emitted at lower velocities and fell back to the surface. A flyby could capture fluid without the energetic cost and complexity of a lander, and the sample could be investigated remotely by instruments in the spacecraft or returned to Earth. Multiple flybys would be necessary to collect enough sample volume for definitive life detection(*5*), but assuming that this may be accomplished, it is still unknown what types of biosignatures might be found in the plumes.

It might be expected that salty water boiling on Enceladus would concentrate microorganisms, perhaps leading to a "snow of microbes" on the surface. A large number of studies in Earth's oceans and lakes have demonstrated that bubble formation serves to concentrate bacteria and organics. On Earth, bubbles burst on the surface of bodies of water, and are injected into the atmosphere in jet drops. The concentration of bacteria and associated complex organics (sugars, proteins, nucleic acids, etc.) in the bubbles and the jet drops can be many times higher than in the original water reservoir (*6*) (*7*). These processes have important implications for the spread of water-borne pathogens, delivery of bacteria to the upper atmosphere, and nutrient cycling. Concentration is more marked in bacteria expressing the red prodigiosin pigment, such as *Serratia marcescens* (*8*).

There are no known terrestrial analogs of the icy plumes of Enceladus, so the concentrations of bacteria, viruses, and complex organics relative to the source cannot be accurately predicted from analog studies. It is known, however, that Earth oceans and lakes differ from Enceladus in several key respects. On Earth, bubbles may form well below the water surface, and entrain bacteria and organics as they rise. Cells also gather at the ice/water interface due to cellular requirements for oxygen and sunlight. Neither of these applies to a cold, anoxic moon where bubbles arise from water boiling into vacuum. The only readily available way to test bubble-related concentration in an Enceladus model is to construct a laboratory mock-up of the ocean seeded with complex organics and bacterial cells, and measure the resulting concentrations in simulated plumes.

Methods and Results : Our eventual goal is to create a laboratory simulation of the plumes. The first step in the work, presented here, is to create a system for measuring bacterial concentrations in jet drops from bubbles bursting under vacuum. We built a turntable apparatus for reproducible generation of bubbles of controlled sizes, which may be operated outside or inside of a vacuum chamber (**Fig. 1**). In the chamber, the low-pressure environment results in energetically different bubbles from what is seen under normal atmosphere, with increased bubble size. We measured bacterial concentration in jet drops collected 10 cm from a liquid surface, comparing normal pressure and vacuum using 3 bacterial species: *S. marcescens*; *Colwellia psychrerythraea* 34H, a marine strain that produces prodigiosin; and *Bacillus subtilis*, an unpigmented soil bacterium. These results suggest that bacteria might indeed be concentrated under low-pressure conditions, but that the degree of concentration is highly strain-dependent.

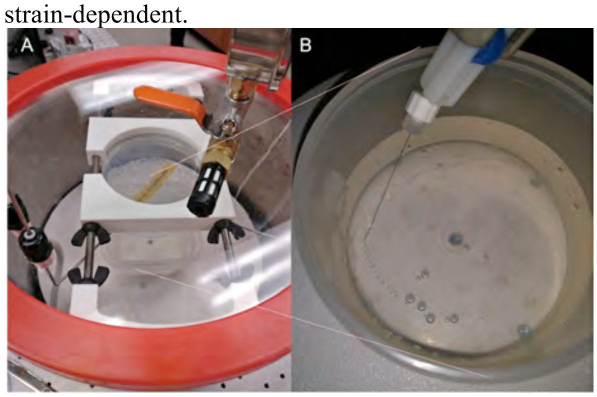

Fig. 1. (A) Vacuum chamber containing turntable and fine needle for bubbling. (B) Stream of bubbles of controlled sizes.

References:

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