Detecting potential biosignatures in cryovolcanic plumes at Enceladus and other ocean worlds

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Description:

- Conduct pioneering simulation experiments investigating the formation of cryovolcanic plumes at Enceladus and their analysis with spacecraft instrumentation.
- Develop a highly interdisciplinary skillset with elements of low-temperature aqueous geochemistry, organic chemistry and impact ionisation time-of-flight mass spectrometry, alongside data synthesis and scientific writing.
- Join a large interdisciplinary group (AstrobiologyOU) with involvement in many aspects of the search for life beyond Earth; engage with Cassini and Europa Clipper mission instrument teams.

The plumes emitted from the South Polar Region of Enceladus have been investigated extensively by the Cassini mission. Returned data implies they are fed by a global subsurface ocean in contact with a silicate interior [1]. Based on Cassini's observations, it is thought that hydrothermal activity at the core-ocean boundary may provide the necessary conditions to support microbial life [2]. Hence, Enceladus has come to be recognised as one of the most important targets in the Solar System for astrobiology.

Although the subsurface ocean may be deemed habitable, direct access to it is not currently feasible. Finding evidence of life therefore depends on recognising compounds uniquely produced by microbial activity (biosignatures) within the plumes. Salt-rich icy plume particles, encountered by Cassini's Cosmic Dust Analyzer (CDA) instrument, are thought to originate as rapidly frozen droplets of ocean spray [3], and thus may contain biosignatures from the ocean. However, the mechanisms governing the transfer of potential biosignatures from liquid phase into icy particles are not well understood [4]. Furthermore, the particles encounter the CDA at high velocities (> 1 km s^{-1}), where they undergo impact ionisation [5]. Confirming or ruling out the presence of biosignatures at Enceladus requires accounting for this ionisation behaviour in the presence of salts and other compounds that may co-exist within plume particles.

The aim of this project is to determine the feasibility of detecting evidence of life in the plumes of Enceladus, with relevance for other cyrovolcanically-active ocean worlds such as Europa, using simulation facilities at the Open University and Freie Universität Berlin. The successful candidate will begin by simulating plume particle formation under conditions relevant to Enceladus, using planetary environment simulation chambers and bespoke facilities at the OU for generating micrometre-sized ice grains. The efficiency of aerosol formation and flash-freezing for capturing biosignatures (including diagnostic low and high-molecular weight organic compounds as well as intact microbial cells) from the liquid phase will be investigated using spatially resolved microanalytical techniques (e.g., scanning electron microscopy, micro-Raman spectroscopy) and bulk analyses (e.g., gas chromatography-mass spectrometry). The final stage of the project will investigate the modification of potential biosignatures during hypervelocity impact into spacecraft-based mass spectrometers, using instrument simulation facilities at Freie Universität Berlin. Results from the project will be used to interpret existing Cassini CDA data and future Europa Clipper SUrface Dust Analyzer (SUDA) data.

The successful candidate will join AstrobiologyOU, a dynamic, interdisciplinary group of researchers investigating the scientific, technical and ethical challenges associated with the search for life beyond Earth. They will also work closely with Cassini and Europa Clipper mission scientists at Freie Universität Berlin.

References:

1. Spencer & Nimmo (2013). Enceladus: An active ice world in the Saturn System. *Ann. Rev. Earth Planet. Sci*. 41, 693
2. Waite, J.H., Glein, C.R., Perryman, R.S., Teolis, B.D., Magee, B.A., Miller, G., Grimes, J., Perry, M.E., Miller, K.E., Bouquet, A. and Lunine, J.I. (2017). Cassini finds molecular hydrogen in the Enceladus plume: evidence for hydrothermal processes. *Science*, 356(6334), pp.155-159.
3. Postberg, F., Kempf, S., Schmidt, J., Brilliantov, N., Beinsen, A., Abel, B., Buck, U. and Srama, R., (2009). Sodium salts in E-ring ice grains from an ocean below the surface of Enceladus. *Nature*, 459(7250), pp.1098-1101
4. Porco, C.C., Dones, L. and Mitchell, C., (2017). Could it be snowing microbes on Enceladus? Assessing conditions in its plume and implications for future missions. *Astrobiology*, 17(9), pp.876-901.
5. Srama, R., Ahrens, T.J., Altobelli, N., Auer, S., Bradley, J.G., Burton, M., Dikarev, V.V., Economou, T., Fechtig, H., Görlich, M. and Grande, M., (2004). The Cassini cosmic dust analyzer. In *The Cassini-Huygens Mission* (pp. 465-518). Springer, Dordrecht.

Qualifications required:

The ideal candidates will have a minimum 2:1 in a relevant science degree, such as geosciences or chemistry, or equivalent qualifications. Specialism in planetary geochemistry or organic geochemistry is advantageous, as is laboratory experience.