EEES Project Proposal Form – 2021 entry

Project Title	**OU16 - Detecting potential biosignatures in cryovolcanic plumes at Enceladus and other ocean worlds**
Key words	Astrobiology; Enceladus; biosignatures; icy moons
Supervisory team (including email address	**PI: Karen Olsson-Francis (karen.olsson-francis@open.ac.uk)** **Co-I: Mark Fox-Powell (mark.fox-powell@open.ac.uk)** **Victoria Pearson (victoria.pearson@open.ac.uk)**
Is the PhD suitable for part time study?	Yes ☐ No ☐

Project Highlights:

- 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.

Overview:

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. Recent work has described how ocean fluids behave during rapid freezing [4], however, the mechanisms governing the transfer of potential biosignatures from liquid phase into icy particles are not well understood. 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. The successful candidate will first investigate the transfer of microbial organic compounds from liquid phase into "flash-frozen" aerosol droplets, using bespoke experimental facilities at the Open University. Then, using simulation facilities at the Freie Universität Berlin, the student will investigate

the modification of biosignatures during impact ionisation and the implications for their detection by spacecraft. Results from the project will be used to interpret existing Cassini CDA data and future Europa Clipper SUrface Dust Analyzer (SUDA) data.

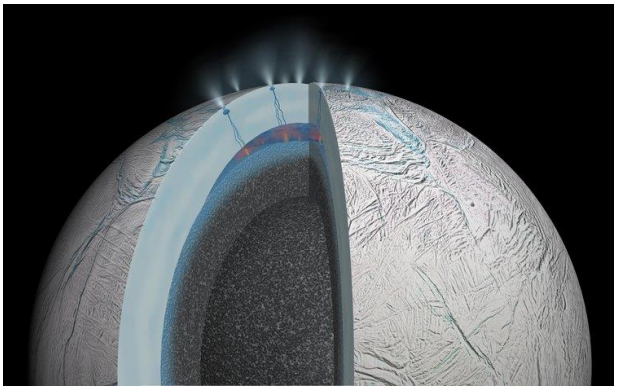

Figure 1: Illustration of the interior of Enceladus showing the global ocean. Credit NASA.JPL-Caltech.

Methodology:

To investigate the feasibility of detecting biosignatures in cryovolcanic plumes, the candidate will:

1. Using bespoke planetary simulation facilities at the OU for generating micrometre-sized ice grains, the candidate will investigate the efficiency of aerosol formation and flash-freezing for capturing soluble organic biosignatures. The composition of frozen droplets will be compared to the source fluid using gas chromatography-mass spectrometry.
2. Building on the results from (1), the candidate will investigate whether microbial cells can be captured intact during plume particle formation, analysing frozen droplets with spatially resolved microanalytical techniques (e.g., scanning electron microscopy, micro-Raman spectroscopy)
3. The candidate will determine, using dedicated spacecraft instrumentation simulation facilities at the Freie Universität Berlin, the modification of potential biosignatures during hypervelocity impact, producing mission-relevant mass spectra.

Results from this project will be used to interpret existing Cassini CDA data and future Europa Clipper SUrface Dust Analyzer (SUDA) data.

Training and skills:

The student will gain training in specific techniques in low-temperature experimental aqueous geochemistry, organic geochemistry and impact ionisation time-of-flight mass spectrometry.

The student will benefit from a diverse training programme, ranging from skills that support their PhD studies, e.g., writing skills, time management, presentation skills, research skills and thesis writing, and skills that prepare them for the future after graduation, e.g., CV writing, and networking, including making active contact with industry and academic partners.

Partners and collaboration:

The student will receive training in the analysis of time-of-flight mass spectra, as well as in the laboratory simulation of molecular ionisation during hypervelocity impacts, at Freie Universität Berlin. The group at Freie Universität Berlin is world-leading in the simulation and analysis of impact ionisation mass spectra, with strong links to not only the Cassini Cosmic Dust Analyzer, but also future missions e.g., Europa Clipper. CDA data from the Cassini mission is also available via Freie Universität Berlin. The student will work closely with other members of AstrobiologyOU who are simulating the subsurface ocean at Enceladus.

Possible timeline:

Year 1: Perform a literature review and design Enceladus ocean analogue fluid. Conduct flash-freezing aerosol experiments.

Year 2: Submit manuscript regarding plume particle formation. Present results at a national conference. Repeat flash-freezing aerosol experiments with microorganisms. Prepare samples for impact ionisation simulation experiments and begin executing these experiments during visits to Berlin.

Year 3: Complete impact ionisation simulation experiments in Berlin and interpret data. Submit manuscript regarding survival of bio-signatures in simulated plume experiment. Write and submit thesis. Present data at an international conference.

Further reading:

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.

Further details:

Students should have a strong background in geosciences, planetary science, organic chemistry, life sciences or a related discipline, and enthusiasm for interdisciplinary science.

If you're not sure whether your academic background is suitable, please contact one of the supervision team or Olivia Acquah at STEM-EEES-PhD@open.ac.uk. We'd be happy to hear from you.

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.

Applications should include:

- A covering letter that includes:
    - Your motivation to study for a PhD in general
    - Your interest in this project in particular
    - The project-specific skills, aptitude and experience you bring to the project
- an academic CV containing contact details of three references, one of whom should be able to comment on your academic abilities.
- and an Open University application form.
    - If you are British, please use the Home form
    - If you are not British, please use the International form

Applications should be sent to **STEM-EEES-PHD@open.ac.uk** **by 12 noon on Monday 1st March 2021.**