The feasibility of *in situ* VOC analysis on icy bodies

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Summary:

This project will conduct a feasibility study of potential instrumentation that could be deployed on future missions to icy moons.

Project Highlights:

- Developing an innovative cryogenic system for ice growth
- Growing ice simulants representative of icy moons
- Establishing utility of instrumentation for future exploration missions

Overview:

To date, knowledge of the composition of the ices on bodies such as Enceladus and Europa are limited to remote sensing techniques carried out by orbiting spacecraft; no ground-truth *in situ* measurement have yet been made. The current level of interest in these bodies is driven, in part, by their potential habitability. Of particular interest are volatile organics, of which CO, CO_2, CH_4, NH_3, C_2H_2, etc. have been detected remotely in the plumes of Enceladus (Postberg et al., 2011, Figure 1) and CO, CO_2, NH_3 and low molecular weight organics detected spectroscopically on the ice surface (Brown et al., 2006). A question remains as to whether the organics detected are the result of photochemistry or are sourced from upwelling from the sub-surface ocean environment. This is important in order to understand carbon cycling within the Solar System, particularly in light of recent results from Cassini that may indicate a complex organic chemistry on the Enceladus ocean floor (Postberg et al., 2018).

The interest in these icy bodies means that opportunities are likely to arise in the future for *in situ* analysis performed by landed spacecraft elements. Ideally, such instruments will not only take surface measurements, but will also be able to access the sub-surface, which is shielded from space weathering.

This studentship intends to simulate the icy conditions likely in the surface and sub-surface, establish extraction protocols to enable those ices to be analysed, and determine the feasibility of utilising state-of-the-art miniature mass spectrometry to characterise the composition of those ices *in situ*. This studentship allows the preliminary evaluation of an *in situ* VOC analytical system for icy bodies in preparation for future mission proposals.

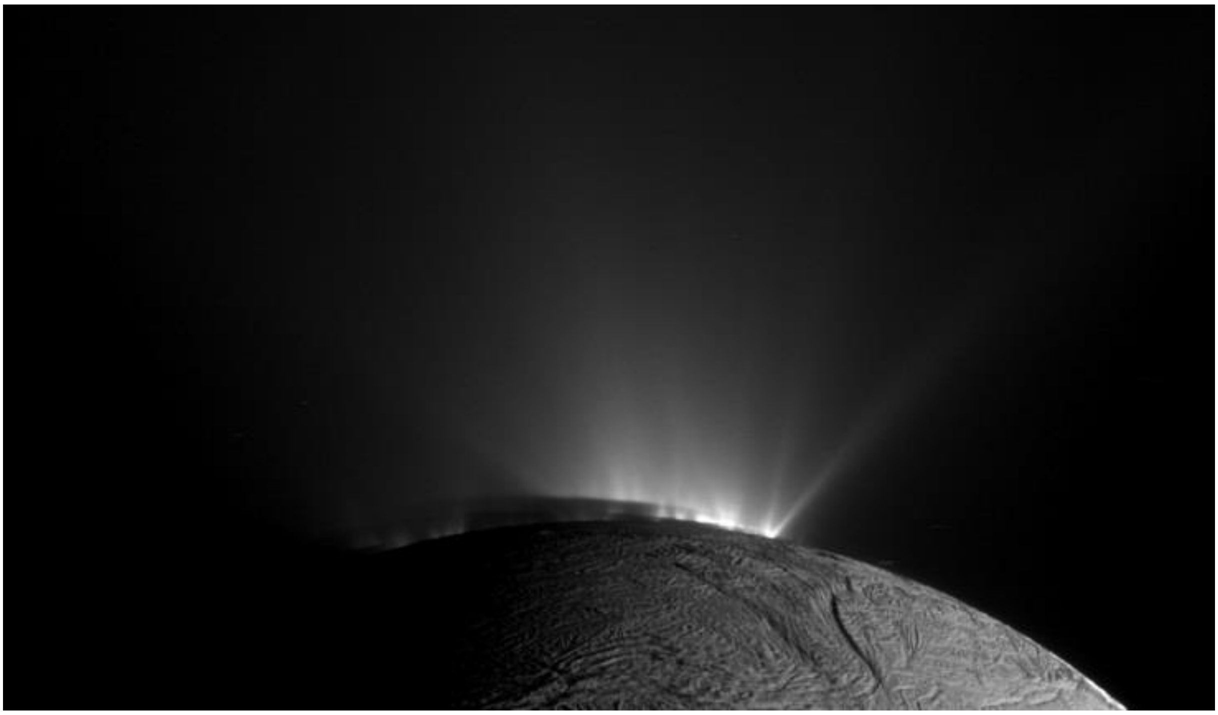

Figure 1 Enceladus' plumes. Photo Credit: Cassini Imaging Team, SSI, JPL, ESA, NASA.

Methodology:

The student will design and commission a cryogenic vacuum system in which ices can be grown under varying environmental conditions. The system will be based on one developed for the LUVMI (Lunar Volatiles Mobile Instrumentation) project but will require modifications. For example, adding a manifold through which different mixtures of volatile organic compounds (VOCs) (e.g., CO, CO_2, CH_4) can be admitted with which to grow the ices.

Ice simulants will be grown, the composition of which will be based on data obtained from orbiting spacecraft, the results of simulations and modelling of icy moon environments undertaken within the OU Astrobiology Research Group, and the results from in situ measurements of Comet 67P/Churyumov-Gerasimenko obtained by the OU's Ptolemy gas analysis spectrometer.

The student will extract VOCs from the ice matrices (e.g., by heating and headspace sampling, volatile extraction through membranes from ice melt, volatilisation) and analyse these using ion trap mass spectrometry (ITMS). They will evaluate the viability and optimisation of existing ITMS systems developed for Ptolemy and LUVMI for icy moon environments.

Training and skills:

The student will receive training in the use of the existing cryogenic system to enable them to modify it for this project. They will be trained to use ITMS systems and the complementary analytical instruments needed to extract and characterise the VOCs liberated.

The student will benefit from a diverse training programme, ranging from skills that support their PhD studies, e.g., writing skills, time management, 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 to industry and academic partners.

Partners and collaboration:

It is anticipated that the Student will collaborate with the LUVMI and other Instrument development teams and it is expected that the experimental work conducted will provide insights into analogue samples for wider use in the group.

Possible timeline:

Year 1 – Perform a literature review and design and commission the cryogenic system. Establish feasible ice compositions (and therefore target gas mixtures) based on existing available data. Optimise the cryogenic system and grow ices. Present results at a national conference.

Year 2 – Prepare and submit manuscript regarding the development of the cryogenic system and its utility to create ice simulants. Establish experimental protocols for the extraction of VOCs and their analysis by ITMS. Present results at an international conference.

Year 3 – Tune the ITMS for the anticipated VOCs. Evaluate the system for potential icy moon deployment. Present results at a national/international conference. Write and submit thesis.

Further reading:

Brown, R.H. (2006) 'Composition and Physical Properties of Enceladus' Surface.' Science, 311(5766), pp.1425–1428. Available at: http://www.sciencemag.org/cgi/doi/10.1126/science.1121031.

LUVMI (n.d.) Lunar Volatiles Mobile Instrumentation. Available at: https://www.luvmi.space/

Postberg, F. et al. (2011) 'A salt-water reservoir as the source of a compositionally stratified plume on Enceladus', Nature, 474(7353), pp. 620–622. Available at: https://doi.org/10.1038/nature10175.

Postberg, F. et al., (2018) 'Macromolecular organic compounds from the depths of Enceladus.' Nature, 558(7711), pp.564–568. Available at: https://doi.org/10.1038/s41586-018-0246-4.

Further details:

Students should a strong background in chemistry or physics, with an interest in space-flight applications and opportunities. The student will be welcomed into AstrobiologyOU and also work with a team that have established heritage in the development of instrumentation for space exploration.

Please contact Simon Sheridan (simon.sheridan@open.ac.uk) for further information.

Applications must include:

- a cover letter outlining why the project is of interest and how your skills are well suited to the project
- an academic CV
- an application form and an Open University application form, downloadable http://www.open.ac.uk/students/research/system/files/documents/Application%20form%20-%20uk-eu_0.docx
- contact details of three academic references

Applications should be sent to STEM-EEES-PhD@open.ac.uk by 5pm on 30th September 2019.

About us:

AstrobiologyOU has recently been awarded a £6.7m 'Expanding Excellence in England' award by Research England to grow capacity and capabilities. This will allow us to expand and bring together expertise in technology, international development and governance to address the scientific and governance challenges associated with the advancement of astrobiology and related space exploration missions. As part of this expansion we will be recruiting new PhD students who will span these discipline areas. Each studentship will play an important role in the growth of AstrobiologyOU.

The PhD candidate joining us for this project will be working in a vibrant interdisciplinary environment, alongside PhD students from STEM, Law and Governance, and Social Sciences. They will also be part of the wider OU student community, which is a friendly and supportive cohort, with regular social events organised through groups such as RocSoc, HookeSoc and the OU Club.