Signatures of organic-salt-ice interactions in the plumes of Enceladus and other icy moons

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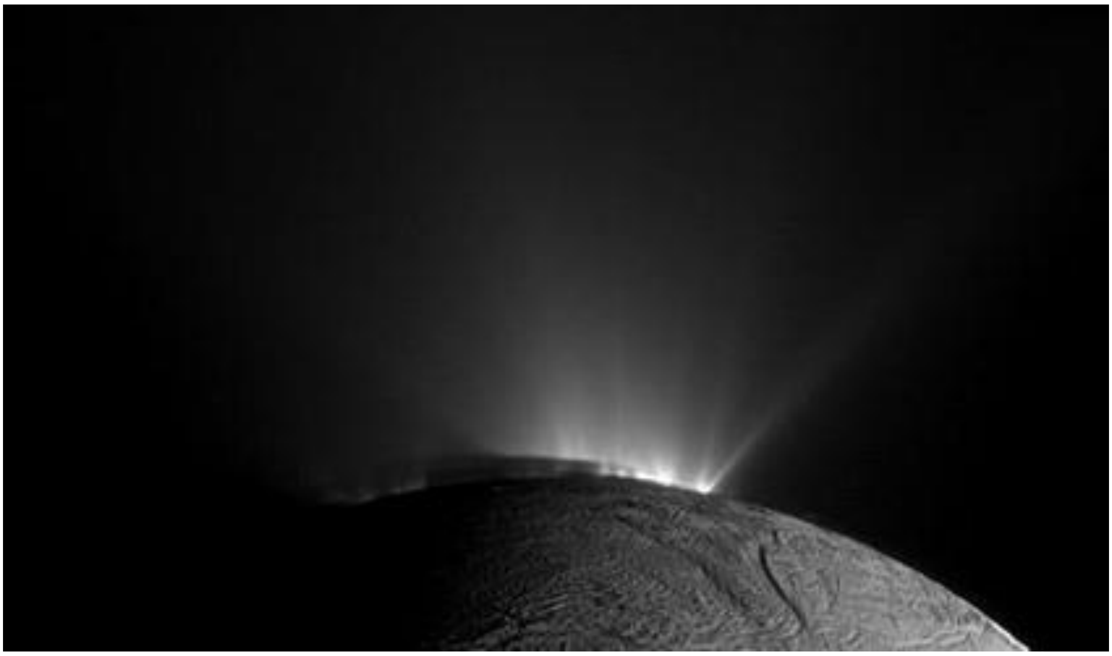

Project highlights:

- Conduct pioneering experiments investigating the formation of organic and salt-rich ice grains in cryovolcanic plumes at Enceladus and other icy ocean worlds
- Develop a strongly interdisciplinary skillset involving planetary environment simulation, laboratory spectroscopy and analysis of spacecraft remote sensing data
- Join a large interdisciplinary group (AstrobiologyOU) with involvement in many aspects of the search for life beyond Earth

Project description:

This project will investigate the formation of salt-rich ice grains in cryovolcanic plumes, such as those at Enceladus. The student will establish how signatures of ice-salt-organic interaction may be expressed in plumes and ultimately detected using spacecraft instrumentation.

Enceladus, a moon of Saturn, harbours a global subsurface ocean that is known to possess favourable conditions for microbial life [1]. While the likely habitable ocean is locked under kilometres of solid ice, cryovolcanic plumes eject materials from the ocean into space, where it can be captured by spacecraft [2]. The Cassini spacecraft encountered microscopic icy particles within the plumes of Enceladus that contained salts and macromolecular organics [3,4], interpreted as rapidly frozen droplets of ocean spray. Deposits of plume fall-out material have also been identified on Enceladus's surface by remote sensing instruments on board Cassini [5].

As droplets of ocean fluid experience extreme changes in temperature and pressure in the plumes, complex interactions between salts, ice and organics are expected [6], with unknown implications for the composition and dynamics of material ejected into space. This project will investigate (1) whether salt-ice-organic interactions within plume ice grains result in compositional and spectral differences between the largest grains (which fall back to the surface) and the smallest grains (which can achieve escape velocity and/or fall out at greater distances from eruption source); and (2) the longevity of these signatures when exposed to micrometeoroid weathering in the space environment.

The student will use a combination of planetary environment experimental simulation, microanalysis techniques and analysis of Cassini remote-sensing datasets to investigate whether signatures of salt-ice-organic interaction can be detected in the plumes of Enceladus. The project will involve the following tasks:
1. Experimentally simulate plume ice grain formation, systematically varying ice grain size, cooling rate, salinity and organic content, to provide comprehensive new context for spacecraft observations of plume material.
2. Collect near infrared spectra under icy moon surface conditions for comparison with spacecraft/telescope data, and analyse ice grain composition and microstructure in detail using electron microscopy, X-ray diffraction, and Raman mapping.
3. Conduct hypervelocity impact simulations to understand potential erosion and/or modification of redeposited plume materials during micrometeoroid weathering
4. Compare results with existing Cassini VIMS data to search for spectral signatures in re-deposited plume materials on Enceladus.

Results from this project will help build a mechanistic understanding of how biosignatures become entrained within cryovolcanic plumes and will be applicable to other ocean worlds such as Jupiter's moon Europa, which will be visited by spacecraft in the coming decade.

References:

1. Spencer & Nimmo (2013). Enceladus: An active ice world in the Saturn System. Ann. Rev. Earth Planet. Sci. 41, 693
2. 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.
3. Postberg, F., Khawaja, N., Abel, B., Choblet, G., Glein, C.R., Gudipati, M.S., Henderson, B.L., Hsu, H.W., Kempf, S., Klenner, F. and Moragas-Klostermeyer, G., 2018. Macromolecular organic compounds from the depths of Enceladus. (2018) Nature, 558(7711), pp.564-568.
4. 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
5. Scipioni, F., P. Schenk, Federico Tosi, E. M. I. L. I. A. N. O. D'Aversa, R. Clark, J-Ph Combe, and C. M. Dalle Ore. (2017) Deciphering sub-micron ice particles on Enceladus surface. Icarus 290: 183-200.

6. Fox-Powell, M. G. & Cousins, C. R. (2021) Partitioning of crystalline and amorphous phases during freezing of simulated Enceladus ocean fluids. Journal of Geophysical Research: Planets 126, e2020JE006628