

## Enceladus' exploration: chemical and biological investigations of water-rich plumes

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One of the most remarkable findings by the Cassini mission is perhaps water-rich plumes erupting from warm fractures near the south-pole region of Enceladus. Given such geological activities and detection of sodium-rich salts in the plumes, Enceladus is highly likely to have an interior liquid ocean interacting with rock materials. These observations raise some primary questions regarding planetary sciences and astrobiology: What is the chemical composition of Enceladus ocean? What kinds of metabolic energy source are available? How and when was Enceladus ocean formed? Does the chemical evolution proceed in the ocean? And, is there life there? Answering these questions would provide a dramatic advance in our understanding of habitability of life in the solar system and could be big breakthrough in almost all fields of natural sciences, including earth sciences, biology, chemistry, and astronomy.

Here we propose a chemical and biological exploration for Enceladus plumes with in-situ and sample-return analyses. In-situ mass spectroscopy with a high-resolution multi-turn TOF MS ( $m/z = 2?1000$ ) would provide the abundances and isotopic compositions of major components of the ocean. Such observational data would allow us to discuss 1) the origin and distribution of volatiles in the Saturn-forming region of the early solar system, 2) biological signatures recorded as anomalies in abundance and/or isotopic compositions, and 3) possible metabolic reactions and energy for chemithoautotrophy. Microscopic analyses for returned samples include synchrotron X-ray analyses, chemical and mineralogical analyses with a nano-SIMS, and calorimetry with radioactive isotopic tracers. Based on results from these analyses, we will be able to 4) characterize physical and chemical conditions of the ocean (pH, hydrogen fugacity, and temperature), 5) discuss the chemical evolution of organic compounds (chemical structure and interactions with minerals), and 6) detect a signature of biological activities.

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