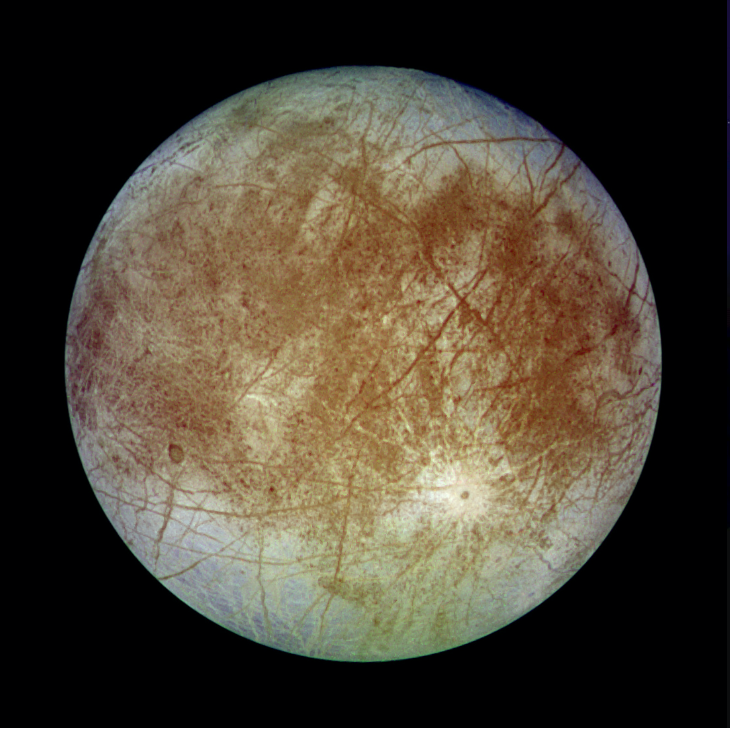
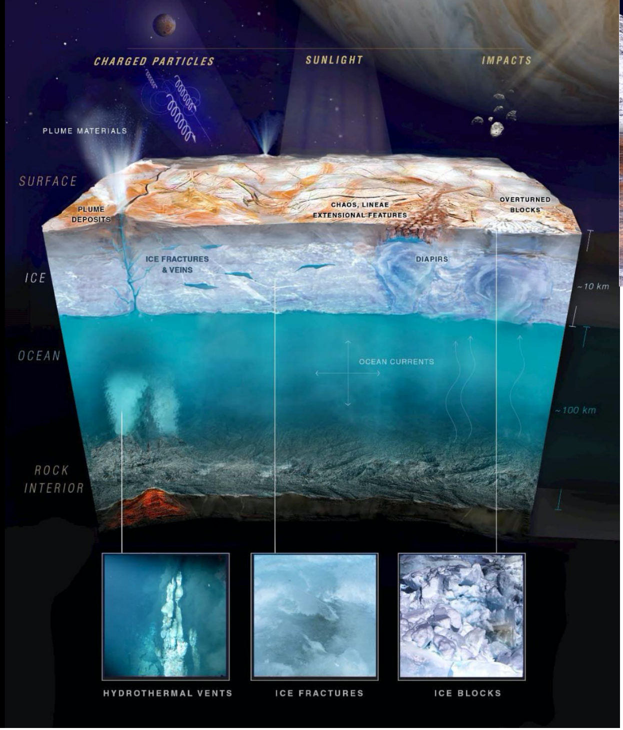
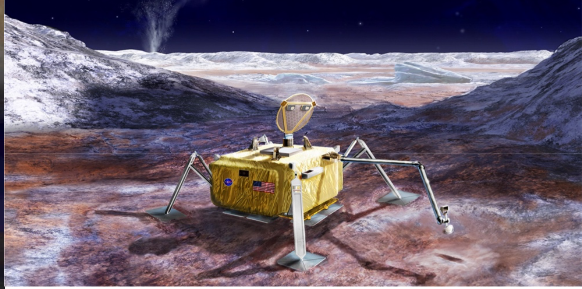
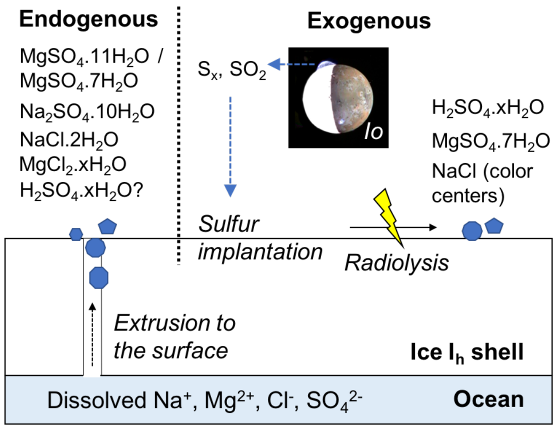








Virtual Research Presentation Conference

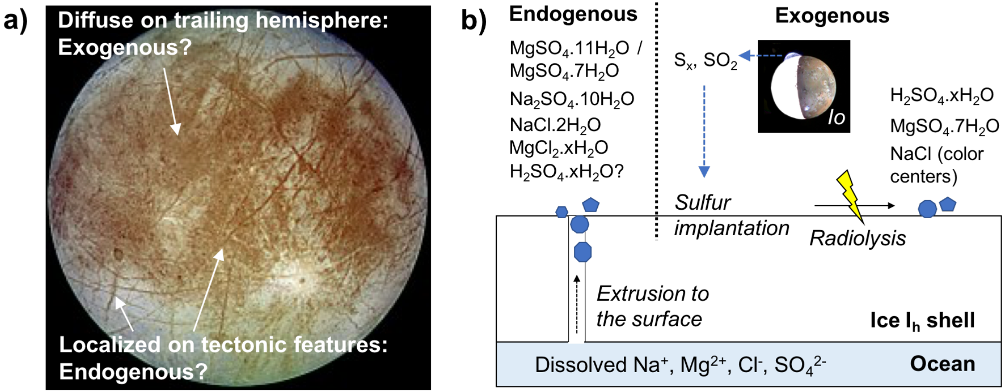
Europa's habitability from surface mineralogy: what a Lander "vibrational spectrometer" may find

Principal Investigator: Mathieu Choukroun (322)
Co-Is: Tuan Vu (322), Joseph Razzell Hollis (322), Suniti Sanghavi (398), Ahmed Mahjoub (Space Science Institute), Robert Hodyss (322), Paul Johnson (322)
Program: Topic

Assigned Presentation #RPC-225

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction



Non-ice materials on Europa's surface are abundant and may have various origins

Abstract

The Europa Lander would aim at finding evidence for life and/or habitable conditions on Europa. The Europa Lander Science Definition Team report suggested a strawman payload that would achieve these objectives; in particular, a "vibrational" spectrometer (Raman is the strawman payload instrument, Infrared considered) is recommended to seek organic and inorganic traces of biological activity and characterize endogenic and exogenic non-ice constituents of the surface.

Although a body of literature exists on the Raman signature of relevant icy minerals (sulfates, chlorides, carbonates, sulfides, oxides, etc.), this literature 1) does not fully encompass the range of possible minerals, due to the numerous hydration states that can be formed within these families at cold temperatures, and 2) does not investigate the minimum detection limit, accuracy of concentration determination, or most suitable instrument parameters. Filling these knowledge gaps is essential to constrain *quantitatively* what such an instrument may find, how well it can achieve its science objectives as function of configuration and parameters, and to prepare adequately for the analysis of scientific data.

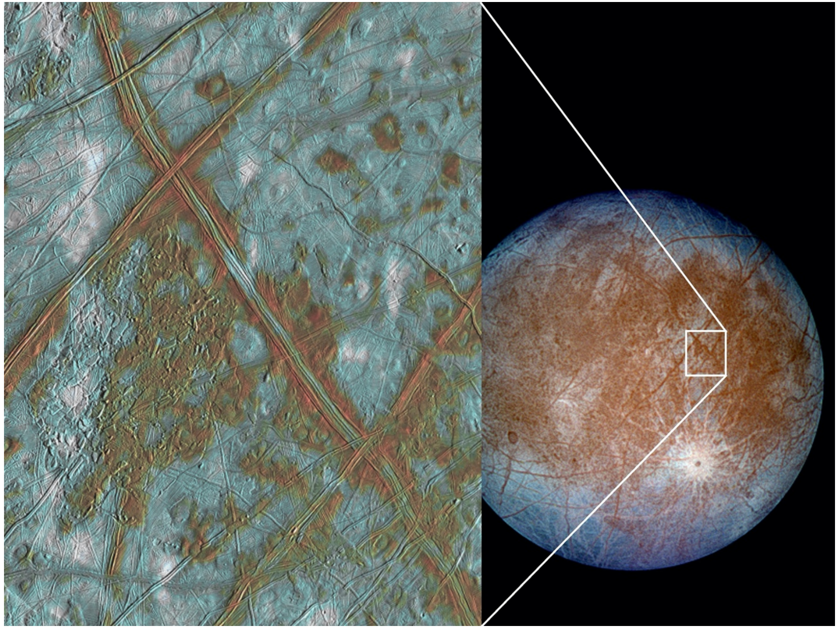
Problem Description

Motivation

The Europa Lander has been a mission concept under study for several years. Its goal is to investigate the habitability and potential presence of life and biosignatures on Europa. This mission concept has been proposed to follow Europa Clipper, which is due to launch by 2025.

The primary goal of this research is to lay the ground work for the development of a performance model for investigating surface materials (salts) with a Raman spectrometer landed on Europa or another Ocean Worlds.

This is required to understand the context of the sample(s): Formed from endogenic or exogenic processes? How much radiolytic processing took place after emplacement? What compositional information on the internal ocean can we derive from these analyses?



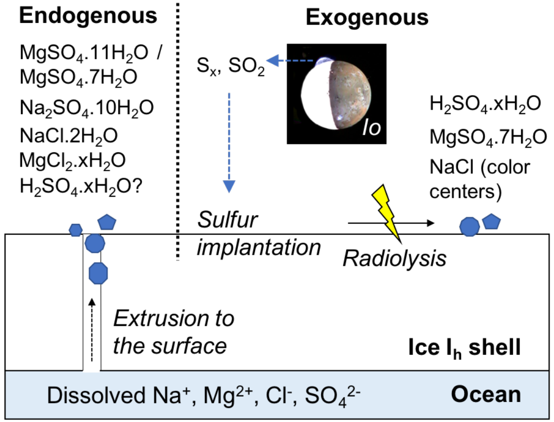
Problem Description

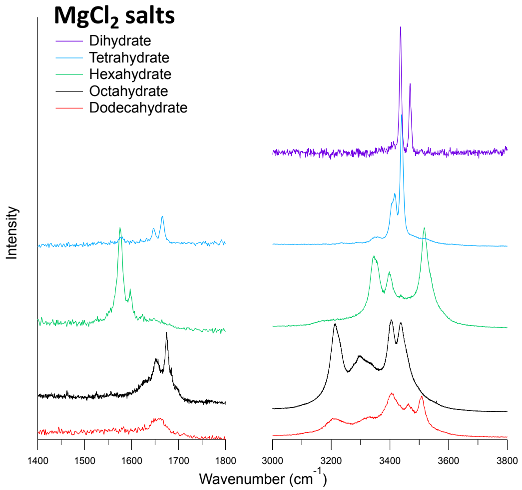
Comparison or advancement over current state-of-the-art

Achieving this goal requires fulfilling the following objectives: 1) Determine accurately and quantitatively the icy mineralogies, including hydration states, that result from freezing of endogenic fluids extruded to Europa's surface. 2) Investigate the influence of a Raman instrument's parameters (excitation wavelength, resolution, acquisition time, spot size), on the performance of detection and accuracy of quantification of the minerals formed.

The first objective is a topic of ongoing research using experiments, modeling, and astronomical observations, which engages the community as a whole. The JPL-led NASA Astrobiology Institute node "Icy Worlds" is at the forefront of this discipline, where *many uncertainties persist* for non-ice materials: phase behavior, hydration states, emplacement mechanisms, etc.

The second objective relies on parameters that would highly depend on the instrument that would equip a potential Europa lander. The Europa lander SDT report recommended for the strawman payload an instrument like the UV fluorescence and Raman spectrometer SHERLOC on Mars 2020. An ongoing ICEE2 project is developing a Raman spectrometer equipped with a green laser. It is therefore important to develop a methodology that would be *applicable to various potential instruments, and other bodies*.



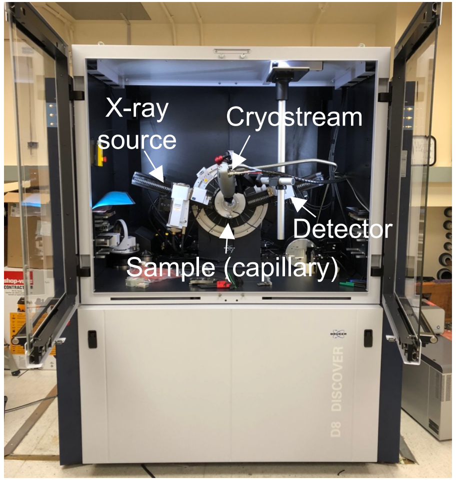


Methodology

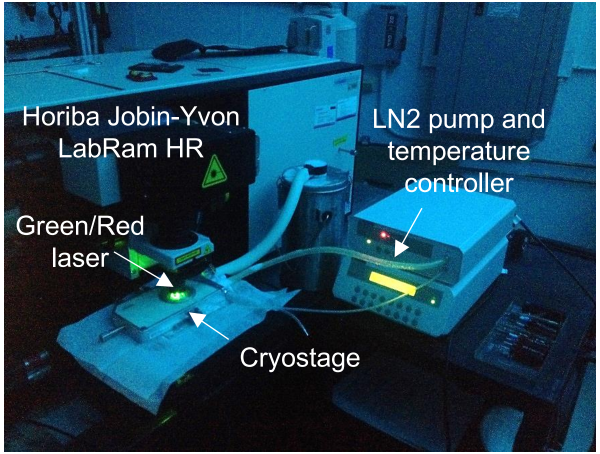
This research uses Cryogenic X-ray diffraction and Raman spectroscopy to investigate experimentally the composition of frozen brines in aqueous salt systems with Mg-Na-Ca-K-Fe cations and SO_4-Cl-CO_3-S anions.

This approach allows us to refine our understanding of the phase behavior in these systems, and test the performance of Raman spectroscopy for detecting and quantifying the phases present under Europa surface conditions.

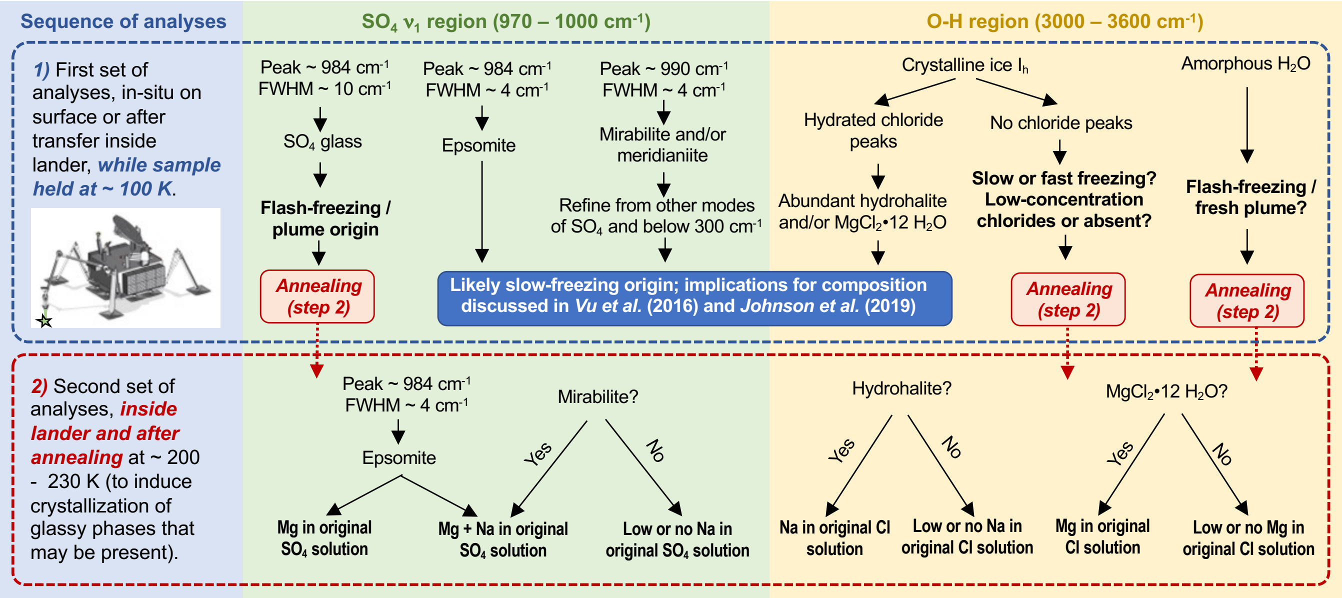
Cryogenic X-Ray Diffraction



Cryogenic Raman spectroscopy



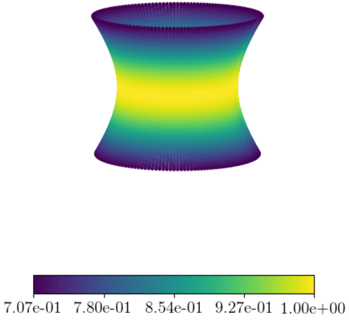
Analysis and interpretation of Europa salts Raman data



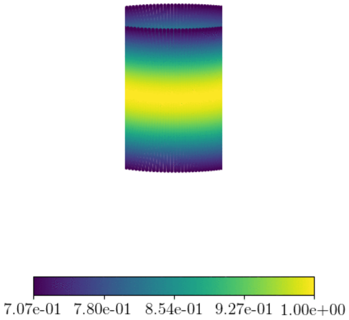
Roadmap for analysis and qualitative interpretation of Raman data of recently exposed areas on Europa. For simplicity, no subsequent surface processing after emplacement is considered. The focus is on the υ_1 symmetric stretch of sulfates, and the hydrogen-bonded O-H modes that are indicative of the state of water ice and of the presence of hydrated chloride salts. Additional spectral regions may need to be analyzed for unambiguous assignments. A dual set of analyses (at 100 K, then after annealing) is required to determine the geologic context of emplacement and constrain the ionic composition of source solutions. Note that non-detection of certain species does not necessarily exclude presence of the constituent ions, as their concentrations could be below the detection limit of the instrument. After Vu et al. (*Icarus*, 113746, 2020).

Green (left) and UV (right) Raman laser beam profiles

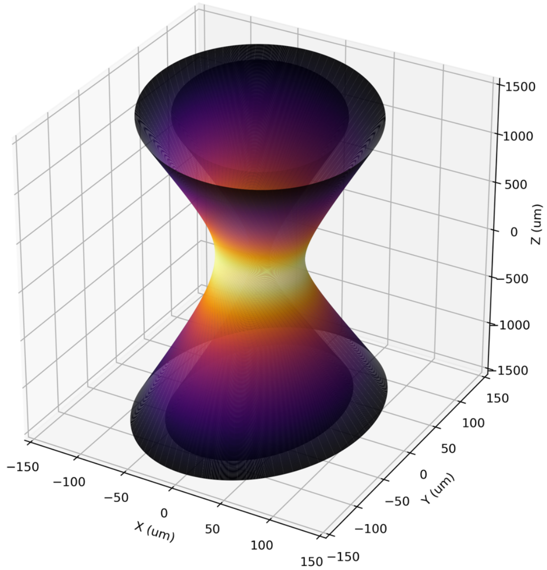
Elliptical beam model (example only, beam will be measured experimentally in FY21):



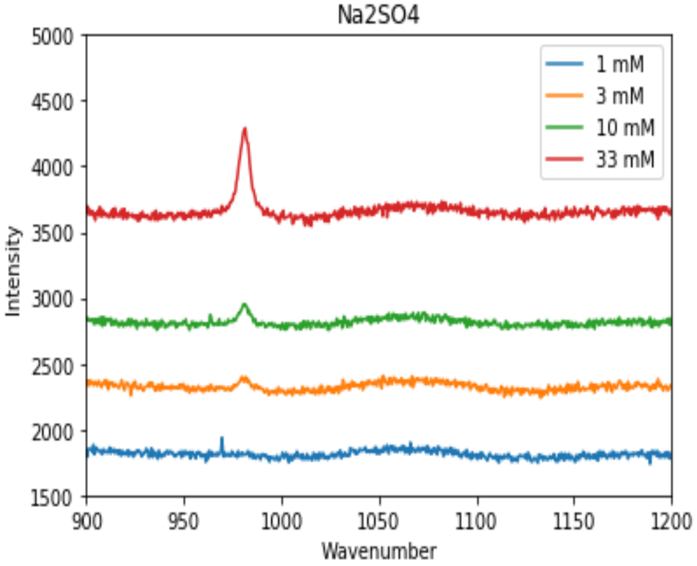
Including a slit that obstructs view of part of the example beam above:

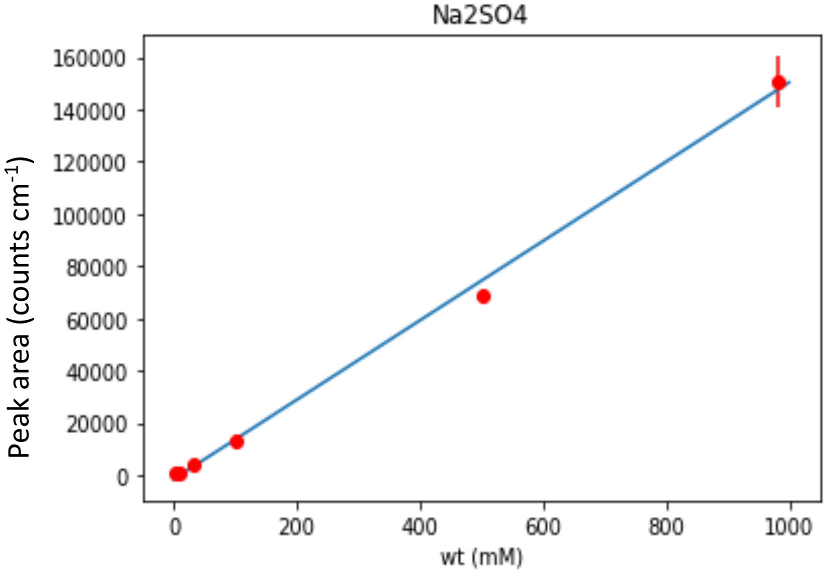


MOBIUS UV instrument beam profile (fully characterized, Hollis et al., *Applied Spectroscopy* **74**(6), pp.684-700, 2020):



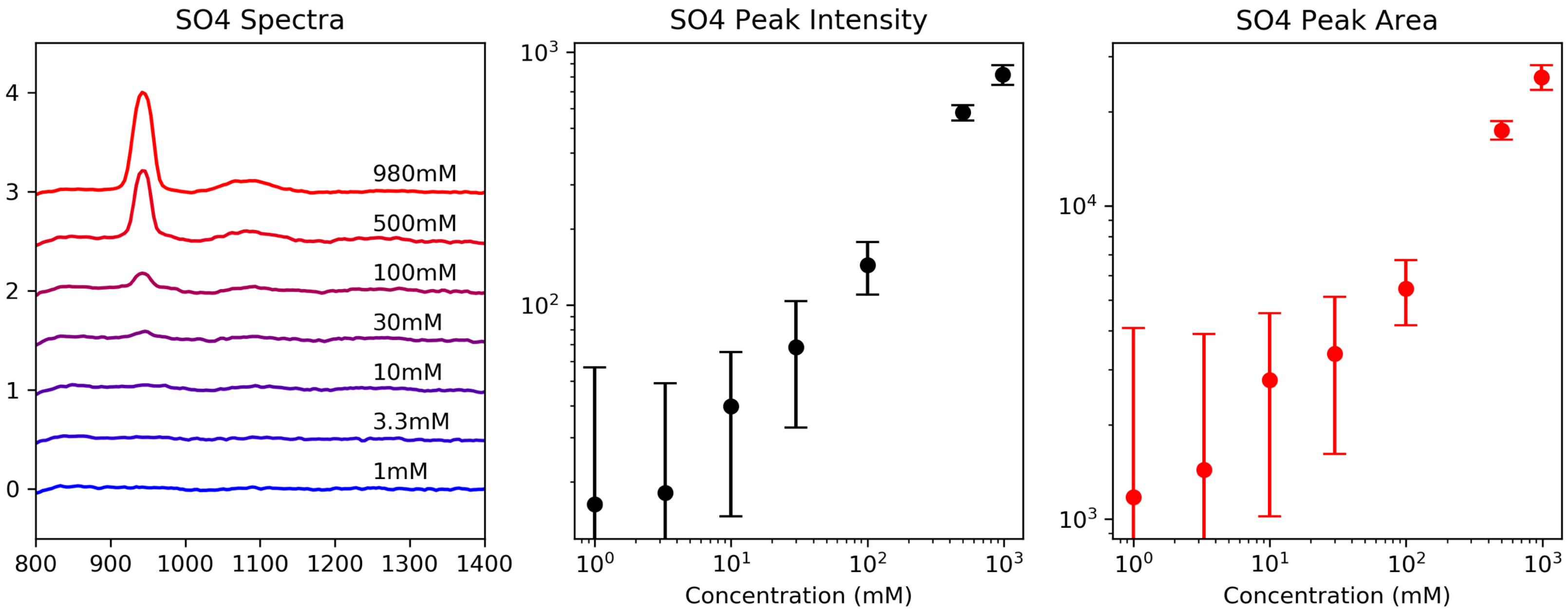
Quantification in aqueous H_2O-Na_2SO_4 with green Raman





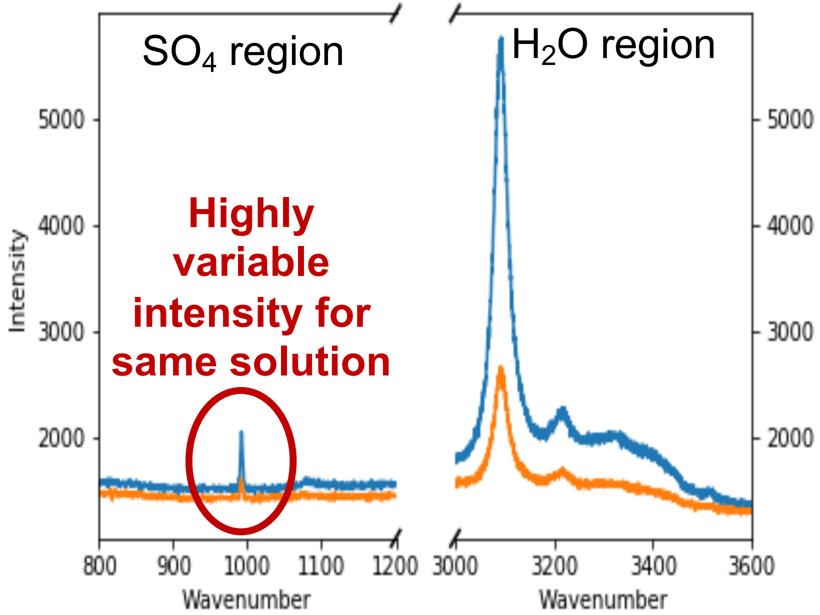
Works very well (linear behavior) from 3 mM up to saturation in liquid solution at room temperature.

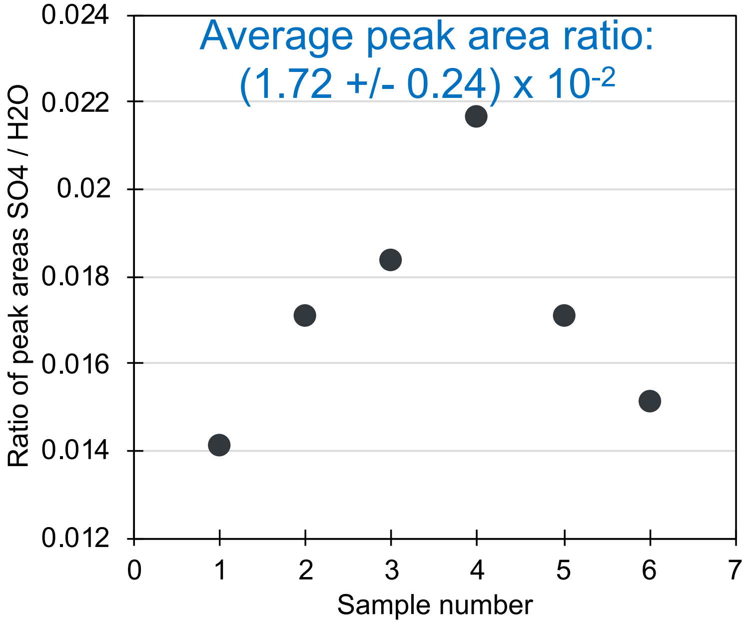
Quantification in aqueous H_2O-Na_2SO_4 with UV Raman



Works well above ~ 10 mM concentration. However, experimental configuration was not optimal and limit of detection can probably be improved to ~ a few mM using a deeper well to enhance amounts of materials probed by the laser beam.

Quantification in frozen H_2O-Na_2SO_4 with green Raman





Unlike in room temperature aqueous solutions, the parameter that follows concentration in 100 mM frozen solutions appears to be not the sulfate peak area, but rather the ratio of areas between the sulfate and the water ice peaks. This will be further investigated experimentally in FY21, and the impact on modeling is *a priori* only moderate.

Publications and References

Publication: Vu, T.H., Choukroun, M., Hodyss, R. and Johnson, P.V., 2020. Probing Europa's subsurface ocean composition from surface salt minerals using in-situ techniques. *Icarus*, p.113746.

Part of this work has been presented at AGU 2019.

References are listed in the slides.