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Detection of cyanobacteria and methanogens embedded in Mars analogue minerals by the use of Raman spectroscopy

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RLS (Raman Laser Spectrometer – one of the Pasteur Payload Instruments onboard ExoMars 2018) will perform Raman measurements on Mars to identify organic compounds and mineral products as an indication of biological activity. The measurements will be performed on crushed powdered samples inside the Rover's ALD (Analytical Laboratory Drawer).
Raman analytics with the same specifications as those onboard the future ExoMars mission are conducted to test their potential of identifying biological material on martian analogue material. Appropriate measurement parameters for the detection of biological material as well as for the determination of the mineral composition will be derived. In addition, we report on problems using Raman spectroscopy to discriminate cells of microorganisms from the mineral background.
Two organisms are chosen as test candidates for potential life on Mars: cyanobacteria and methane producing archaea. Prokaryotes like archaea and bacteria appeared on early Earth at least 3.8 to 3.5 billion years ago (Gya). At this time on Mars the climate was more temperate and wet compared to the present day as inferred from geological evidence for liquid water on the ancient martian surface. Thus life might have developed under similar conditions as on Earth or might have been transferred from Earth (or vice versa). Methane is known to be present on Mars, although the origin (if geothermal or biological activity) is still unknown.
Cyanobacteria and prokaryotes using photosystem I belong to the oldest microbes on Earth. These organisms use pigments such as scytonemin and β-carotene as UV protection. Especially β-carotene emits a strong Raman signal. Raman analytics are used for detection of biofilm forming cyanobacteria Nostoc commune strain on the below described Mars analogue mineral mixtures. N. commune is known to be resistant to desiccation, UV B radiation and low temperatures, and thus suitable as a candidate for a potential life form on Mars.
Furthermore the Raman technique is applied on methane producing archaea candidatus Methanosarcina gelisolum isolated from Siberian permafrost. These archaea are embedded in the martian analogue material for further analysis.
Two different Mars analogue materials containing specific mineral mixtures are used in this investigation. The (1) Phyllosilicatic Mars Regolith Simulant (P-MRS) and (2) Sulfatic Mars Regolith Simulant (S-MRS) reflect the current understanding regarding environmental changes on Mars. Weathering or hydrothermal alteration of crustal rocks and of secondary mineralization during part of the Noachian and Hesperian epoch followed by the prevailing cold and dry oxidising condition with formation of anhydrous iron oxides. The use of two different mixtures is based on observations that phyllosilicate deposits do not occur together with sulphate deposits. P-MRS and S-MRS serve as mineral-matrix in which the cells of the microorganisms are embedded.
Varying periods of measurement time and number of repetitions are performed to get optimal Raman spectra for cyanobacteria and methanogens. A measurement regime is proposed for mineral mixtures with cyanobacteria on the basis of the RLS instrument characteristics. Raman analytics are capable to identify biosignatures like β–carotene on a multi-mineral mixture similar to those expected to be encountered during the ExoMars mission.