Anaerobic iron oxidation: implications for Mars?

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Mars is the 'red planet' for a reason, iron oxidation. It is covered by a thin layer of ferric oxide-rich dust, reflecting the iron-rich nature of the surface. The oxides are not produced by reactions with free oxygen, which is near non-existent in the atmosphere, but possibly by contact with transient briny frosts or peroxide [1] or irradiation of surface compounds to release oxygen. Other oxidisers, such as nitrate [2, 3] and perchlorate [4], have been detected at the surface. Under the dust, reduced iron exists in minerals, glasses and ferrous sulfates. The atmosphere of early Earth was depleted in oxygen, with most iron oxidation attributable to microbes [5]. On Earth today, iron is rapidly oxidised at the surface by free oxygen in the atmosphere, but also by diverse iron-oxidising microorganisms across many niches.

Most modern iron-oxidising microbes convert the reduced Fe(II) form of iron to oxidised Fe(III) aerobically, usually in acidic environments. However, a small subset is able to complete this process in the absence of oxygen. Of these, most are anaerobic phototrophs, but a few use nitrate (and occasionally perchlorate) as a final electron acceptor for Fe(II) oxidation in circumneutral pH sediments, which existed in ancient lacustrine environments [6] and persists [4] on Mars. Autotrophic growth has been confirmed utilising nitrate, but not perchlorate, in this way.

In this study, we will investigate whether nitrate-dependent iron oxidation is a feasible metabolism for the sub-surface environment of Mars, and identify biosignatures which may persist in the Martian regolith through characterisation of microbe-mediated mineral alteration. Growth experiments will be carried out using Fe(II)-bearing minerals such as olivine and pyroxene, which have been identified on the surface of Mars, in nitrate or perchlorate-supplemented media. Known nitrate-dependent iron oxidisers will be used, such as *Thiobacillus denitrificans*, *Paracoccus pantotrophus* strain KS1 and *Pseudogulbenkiania sp.* strain 2002 [7-9]. In parallel, we will isolate novel iron-oxidisers that can utilise nitrate and/or perchlorate as electron acceptors. Enrichments have been prepared from contaminated sites located in the River Dee estuary (North Wales) and Honeycrook Burn in Northumberland using selective media. The outcomes of this study may give insights into a feasible metabolism in the sub-surface of Mars and could lead to identification of geochemical bio-signatures of past or present life on Mars.

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The search for, and appraisal of, carbonaceous matter on Mars

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The Noachian (>3.7 Ga) was the only period in Mars' history at which time significant standing water, a relatively dense heterogeneous and insulating atmosphere, plate tectonics, a magnetic dynamo and the nutrient cycling resulting from this dynamic geological system might have existed concomitantly. Consequently, this is the sole period in the planet's history for which surface habitability could have been sustained [1] . Mars' smaller size would have resulted in its rapid planetary evolution when compared with Earth [2] , the early "death" of its dynamo and consequent devastation of the surface biosphere.

The most accurate available analogue for the Noachian Mars is the Early Archaean Earth (3.85-3.3Ga). Martian volcanic sediments, and environments, such as standing bodies of water [3] , shallow, littoral shorelines [4] and short-lived oases of water in craters and other depressions [5] and, further, the biospheres they contain, can be best appraised by studying their counterparts in the Archaean geological record.

Our approach to studying these biosignatures is focussed on the nature of the carbonaceous material in >3 Ga rocks from the Barberton and Pilbara regions. Using a complementary suite of techniques commencing with optical petrographic study and Raman spectroscopy at the mm- to µm-scale, we seek to elucidate the spatial and geochemical contexts of carbon in the Archaean record. These measurements could shed light on enigmatic organic and mineralogical biosignatures, and will yield datasets directly comparable with those gathered by the CLUPI and RLS instruments (ExoMars) or SuperCam and SHERLOC (Mars2020). The specific nature of the carbon is pivotal i.e. its genesis and alteration with geological time.

Using a combination of SEM, particle induced X-ray emission (PIXE) spectroscopy, laser-ablation ICP-MS and SIMS, the µm-scale elemental, mineralogical and geological associations of carbon can be determined at flexible spatial scales. Uniting multiple techniques can shed further light on the genesis of carbon. Organic carbon in Archaean sediments is of biological, detrital/abiotic (e.g. organics produced by Fischer Trospch synthesis) and probably extraterrestrial origin. In single layer of sediment, a combination of types can occur; this co-location complicates the assessment of the biogenicity of primary structures. Imagine, on a Noachian palaeoshoreline, organic matter derived from a putative Martian chemotrophic biosphere, organic matter emanating from the hydrothermal hot springs and volcanic epithermal systems which would likely have been very common due to the high heat flux on the ancient Mars, and organic matter deposited by the unceasing influx of extraterrestrial matter. The resulting mélange holds pivotal information on Martian carbon.

The characterisation of the nature of carbonaceous material in our Noachian analogue rocks is a complex procedure demanding of a multi-technique approach. Without in situ geochemical measurements of carbonaceous material on the Martian surface or by conducting similar experiments on returned samples, it will be difficult to disentangle the relative contributions of abiotic and putative biotic sources.

We gratefully acknowledge financial support from both CNES and the MASE project (supported by European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n° 607297.

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Surface Attachment of Ribonucleic Acid Monomer on Spinel Ferrite Nanoparticles: A Prebiotic Chemistry Scenario

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Abstract

The interaction between nucleotides (nucleic acid monomer) and mineral surfaces is of primary importance in the context of chemical evolution and origin of life issue. It is a shared opinion that minerals catalyzed the formation of biomolecules by adsorbing monomers on the surface so that condensation reaction could easily occur. Moreover, they have shielded the adsorbed biomolecules from the destructive effects of ultraviolet (UV) radiations and enzymatic degradtion. Metal oxides are recognized as an essential component the Earth's crust and therefore the possibility of these materials acting as an adsorbent for ribonucleotides in the course of chemical evolution can not be ruled out. Recently our attention has been drawn by metal ferrites, an important spinel group of minerals, having general formula $A^{II}B_2^{III}O_4$ where A may be Zn, Ni, Co, Cu, Mn, etc., and B= Fe. Spinel ferrites belong to the members of binary oxide family such as jacobsite ($MnFe_2O_4$), franklinite ($ZnFe_2O_4$), trevorite ($NiFe_2O_4$), cuprospinel ($CuFe_2O_4$), magnetite ($FeFe_2O_4$), ulvospinel ($TiFe_2O_4$) and cobalt ferrite ($CoFe_2O_4$) with considerable magnetic properties and are found in the Earth's crust, upper mantle and meteorites. Trevorite is a well-known spinel metal ferrite ($NiFe_2O_4$) found in Orgueil meteorite, Soltmany meteorite and also recently discovered from Khatyrka meteorite. No studies seem to have been made using such compounds in respect of chemical evolution. Keeping in view of this, the results of work on surface binding of ribonucleic acid monomer, 5′-CMP, 5′-UMP, 5′-GMP and 5′-AMP, with spinel ferrite ($NiFe_2O_4$, $CoFe_2O_4$, $CuFe_2O_4$ $MnFe_2O_4$) nanoparticles of size (11.4-21.7 nm) in the concentration range of $1.0X10^{-4}$ M-$4.0X10^{-4}$ M at three different pHs (4.0, 7.0 and 9.0) have been reported. The maximum percent binding was found at pH 4.0 for all the ribonucleotides studied. The nickel ferrite ($NiFe_2O_4$) showed higher percent binding (82-97%) while manganese ferrite ($MnFe_2O_4$) exhibited lowest (34-67%) adsorption affinity for all ribonucleotides. Experimental results showed the participation of different functional groups (amine, phosphate and carbonyl) of nucleotides in binding process. The results of this study show that spinel metal ferrites as a better candidate towards the adsorption of nucleotides as compared to earlier studied metal oxides such as alumina (acidic, neutral and basic), ZnO and manganese oxides (MnO, Mn_2O_3, Mn_3O_4 and MnO_2). Thus, the present study suggests that spinel ferrite minerals might have played important role in the context of prebiotic chemistry and origin of life by concentrating the important biomonomers in the primeval soup.

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Iqubal, M. A., Sharma, R. and Kamaluddin (2016) Surface Interaction of Ribonucleic Acid Constituents with Spinel Ferrite Nanoparticles: A Prebiotic Chemistry Experiment ***RSC Advances.,*** DOI: 10.1039/C6RA12247G.

Raman spectroscopy and imaging methods for the detection of biomarkers

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In our Solar System, Mars is considered one of the prime candidates to have spawned life. Although the current climate on Mars is very harsh, the planet is believed to have been much more habitable in the past. Any possible current life on Mars must be able to withstand the extreme drought, radiation levels and temperature swings. Earth has examples of organisms that fit this profile, such as *D. Radiodurans[1]*, hence terrestrial habitats that host extremophiles are the subject of intense study.

Due to current payload constraints, most complex analytical techniques are not feasible on missions to Mars' surface. The ExoMars 2018 rover will be equipped with a Raman spectrometer. This spectrometer has some potential to detect biosignatures, but will mainly focus on the characterisation of the mineralogy of individual habitats. This report focuses on assessing the next generation space instrumentation for life detection, using carotenoids, a widely accepted proxy for biosignatures[2]. To obtain an increase in specificity and signal to noise ratio, we are optimising the excitation wavelength for resonance Raman spectroscopy (RRS).

Due to the high radiation levels on Mars, it is expected that any present life would reside beneath the surface, hence β-carotene and various bacteria were measured embedded in different mineral environments. We report two scenarios: 1. living organisms behind a several millimetre thick surface; 2. living organisms deeper below the surface. In the first case, time-resolved Raman spectroscopy can help us to 'look through' translucent minerals. Previous research has already shown that it is possible to detect Raman signal of *D. Radiodurans* through a translucent mineral layer of several millimetres thick[3]. For the second scenario, measurements will have to be performed on samples obtained by drilling up to a few metres deep. In this case, life could be hidden anywhere in the sample. As a proxy for such samples, we measure spectra from different mixtures of β-carotene or bacteria with minerals of different composition and varying grain sizes. We vary bacteria/carotene concentrations to quantify our detection limits and optimise our set-up for the detection of biomarkers. Our goals are to optimise our own set-up for the detection of biomarkers in a mineral environment and to develop methods that could be used to detect possible life on Mars. The results of our research will add to the preparation for future Mars missions and can increase our chances of detecting life on Mars.

In addition to the work with the time-resolved set-up, our research is examining ways to make the Raman collection efficiency larger using mapping approaches. We will compare Raman imaging using; line mapping, global imaging, or fibre-array imaging. Line mapping uses cylindrical lenses to not focus on a spot, but focus on a line. In the case of a vertical line, the vertical axis of the spectrometers' CCD camera then registers the vertical location on the sample and the horizontal axis registers wavelength. Because a larger area is imaged at one instance, and the CCD is used more effectively, this method is significantly faster than point mapping. Another equally fast method is fibre array imaging. In this approach, there is - like in line mapping - one spatial axis and one spectral axis on the CCD, but the fibres can be used to measure a square surface in one measurement. This means that scanning is not necessary, making it possible to simplify the set-up. Global mapping images a large surface directly onto the CCD, but only one wavelength - or wavenumber - is measured at a time. This method can be very fast if only a small number of peaks are investigated, but is less efficient than line-mapping when many wavenumbers are scanned. The number of different wavenumbers that can be scanned whilst retaining the faster measurement speed depends largely on the power density that is still possible to achieve on the sample. Therefore, the applicability of this methods ultimately depends on the development of more energy efficient, higher power lasers suitable for space missions.

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Metalation of a Model Porphyrin in Simulated Primordial Tide Pools: Possible Prebiotic Formation of Porphyrin-Type Cofactors

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The Hadean/Early Archean Earth was probably covered by a planet-wide ocean. At that time, volcanic islands may have been the only landmasses and were promising places for chemical evolution, since they offered various geochemical and geophysical conditions, such as different temperatures, pH values, and mineral catalysts (Strasdeit 2010). Tide pools at the coasts of these islands can be regarded as chemical reaction vessels. In corresponding simulation experiments, our group has demonstrated the formation of alkylpyrroles, and subsequently alkylporphyrins, starting from simple amino acids (Fox and Strasdeit 2013). Due to their exceptionally high stability and water insolubility, alkylporphyrins could have accumulated in rock pools near the coasts.
Today, porphyrins are very common biological molecules. In the form of their metal complexes (e.g. hemes, chlorophylls, cobalamines) they are involved in fundamental metabolic processes (Kaim et al. 2013). Consequently, it seems plausible that metalloporphyrins were among the first biomolecules in early organisms or even earlier in prebiotic protometabolisms (Strasdeit and Fox 2013). In synthetic chemistry, metalloporphyrins are typically prepared according to Adler et al. (1970) by using metal acetates in refluxing N,N'-dimethylformamide. Neither the starting metal compounds nor the solvent are prebiotically plausible, and finding a “prebiotic” replacement appears to be difficult. Recently, we investigated the possibility of metalloporphyrin formation from a model alkylporphyrin (octaethylporphyrin) and “Hadean” minerals under simulated tide pool conditions. These experiments included different minerals, different aqueous media (e.g. freshwater, salt water, neutral and acidic) and the simulation of tides by wet/dry cycles. For this purpose, a special apparatus was designed which allowed the automated time-controlled execution of wet/dry cycles under an inert atmosphere. Strict exclusion of oxygen was important, as Earth's early atmosphere contained virtually no free oxygen near the surface. In addition to minerals, also rocks, iron meteorites and metal salts were used. We mainly focused on iron sources, because iron is among the most abundant metals in Earth's crust and a constituent of the porphyrin-type electron transfer cofactor heme.
Despite the water insolubility of our model porphyrin, we observed metalation reactions in the wet/dry experiments. According to these results, early ancestors of porphyrin-type biological cofactors could have been formed abiotically from alkylporphyrins at volcanic coasts. Thus, metalloporphyrins may have been involved in prebiotic reaction networks and protometabolisms. Detailed results, including the yields of the metalation reactions (which were up to 54 %), will be presented, and their possible relevance for chemical evolution will be discussed.

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The importance of cave environment for exobiology: a new type of microbially-mediated unusual helictites found in Asperge cave (France)

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Karst systems and caves can represent an analogue environment for Mars (the Red Planet) and an alternative place where Earth biosignatures can be preserved. Lately, several caves, and in particular lava tubes, have been studied to understand subsurface microbiology and to test, for instance, the ability of robots in detectinting microbiological patterns, such as biovermiculation. Lava tubes are the most studied caves as they are very abundant in volcanic regions, they can be easily discovered and observed by Remote Sensing techniques, they have metric-decametric size entrances, smooth inner morphologies and quite flat floors that are suitable for robotic experiments. But, lava tubes are also important for the significant presence of unique microbial communities.
On the other hand, our planet has other types of caves that can host microbially-mediated structures, such as stromatolites and thrombolites, or unusual speleothems characterised by rising morphologies resembling, for instance, U-loops.
Here we describe and explain the genesis of the unusual speleothem morphologies found in Asperge cave (France), especially focusing on mineralogical phases, singular inner structure and their possible interaction with specialised microbial communities.
Asperge Cave, located in the region of Montagne Noire-Hérault (France), develops in Cambrian rocks along the contact between phyllites and marble; it is a 7 km long cave reaching 126 m of depth. It is a quite bare cavity with a limitated portion of blue and white bundles of helictites with acicular and coralloid shapes, coming up from roof and walls.
The helictites in Asperge cave are characterised by several unusual features such as preferentially upward growth, splitting, and formation of bridges and bights. They show a singular way to merge and a well-visible inner tube (very different from the one ruled by capillarity action). Using SEM and µCT-scan we have had the possibility to observe that biofilm is a fundamental component of their structure, that acting as preferential site for minerals nucleation is very strongly associated with calcite crystals. We propose that the above described speleothems are microbially-mediated structures and may represent a new kind of macroscopical biosignature.

Keywords: speleothems; biogenic mineralisation; geomorphology; microbiology; terrestrial carbonates

Floating in space: Influence of simulated microgravity on B. subtilis biofilm formation – An electron microscopic study for whole biofilm analysis

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Bacillus subtilis was already used in several space missions and served as spore-forming, Gram-positive model organism (reviewed in Horneck et al., 2010). Since it is known that planktonic life is the exception, biofilms are considered as predominant way of living (Moons et al., 2009). Several wild-type strains of B. subtilis like the undomesticated NCIB 3610 are recently investigated regarding their ability to form biofilms, including the underlying genetic regulation and their enhanced environmental resistance (Vlamakis et al., 2013, Cairns et al., 2014). Biofilms consist of a self-produced extracellular polymeric matrix, composed of a mix of polysaccharides, proteins, nucleic acids and the complex organisation of all attached cells. Living in a biofilm is very advantageous for the community, because the matrix, covered with a hydrophobic protein layer, protects the single cell from external changes. Cells in a biofilm are protected against shear forces, chemicals (e.g. antibiotics or disinfectants), temperature changes and water as well as nutrient depletion. Biofilm formation under spaceflight conditions, especially microgravity, and the possible impact for the crew – regarding the extreme environmental resistance of biofilms – has not been studied yet. The impact of possible changes in microbial resistance due to changes in gravity and radiation is still unclear. Especially long term missions with complex cooling systems, water supply and heat pipes may be vulnerable by biofilm colonisation.
In our work, we studied the impact of a reduced influence of gravity from early developmental stages to maturated B. subtilis biofilms. Our major research goal is to compare and quantify biofilm formation of B. subtilis in simulated microgravity (2D fast rotating clinostat, German Aerospace Center, DLR, Cologne) compared to terrestrial gravity conditions by using different microscopic techniques (Robert Koch Institute, RKI, Berlin).
Therefore scanning and transmission electron microscopy (SEM, TEM), confocal laser scanning microscopy (CLSM) and light microscopy were used to cover different stages of biofilm development.
Future human and robotic spaceflight missions will struggle with bacterial contaminations. Therefore it is of utmost importance to understand the underlying mechanisms of biofilm structures to preserve international planetary protection guidelines.

Keywords: biofilm, B. subtilis, whole biofilm analysis, microgravity, SEM, TEM, CLSM

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T082-The influence of salt composition on the entombed microbial community within the deep sub-surface Boulby Mine

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Halophiles (salt loving microbes) are often proposed as a model organism for analogue studies of potential martian life [1] because atmospheric conditions on Mars are such that liquid water could only exist in the form of highly concentrated brines [2]. The case for halophiles as martian analogue organisms is further strengthened by their extreme resistance to ultraviolet radiation [3], their close relation to some of the most cold-tolerant organisms on Earth [4], and the knowledge that anaerobic halophiles exist [5]. While no known terrestrial halophiles could survive on the present day surface of Mars, environmental conditions are believed to have been more hospitable to life in the distant past, and, as the conditions worsened, organisms analogous to halophiles would have been able to survive for longer than others [6].
There is now strong evidence that microbes, and specifically haloarchaea, can survive inside halite crystals for millions of years [7-9] and that entombment in halite protects against Mars-like conditions [3]. This raises the potential for the preservation of ancient martian life in subsurface halite crystals, either as broken cellular components or even as viable cells [10]. While martian salt deposits are known to exist, they are unlikely to consist of sodium chloride in the concentrations found on Earth [11]. It is therefore important to assess the impact that different ion compositions have upon long-term entombment of halophiles in salt crystals, in order to determine the value of these martian sites as potential refuge for life.
Boulby Mine in Yorkshire is a potash, halite and polyhalite mine. It is the second deepest mine is Europe and is used as an analogue site for the testing of instrumentation for future Mars missions [12]. Samples were collected from the mine, at a depth of roughly 1 km beneath the surface of the North Sea, 4km north of the British coast line, within 5 m above and below the interface between potash and halite beds. Four sampling sites were chosen over an area of 0.1 km2. From these sites, samples were collected of the potash, the halite and the interface between these two beds (where halite and potash were both present).
Inductively Coupled Plasma Mass Spectrometry (ICP-MS) confirmed the composition of the samples, with sodium concentrations of 25% in the potash (compared with 40% within the halite), and potassium concentrations of 10-25% in the potash (negligible concentrations in the halite). Potassium concentrations were between 1-5% within the few cm either side of the interface. Calcium varied from 0-5% and was heterogeneously distributed through each bed; it could be suggested that calcium concentrations decrease down the stratigraphic column. It is assumed that chlorine concentration corresponds to the total of the sodium and potassium concentrations.
Samples of the rocks were surface sterilised using the acid/bleach bath protocol of Sankaranarayanan et al. [13]. DNA was extracted directly from the rocks and Terminal Restriction Fragment Length Polymorphism (T-RFLP) was carried out. This allows direct comparisons to be made between the composition of the salt and the microbial community entombed within. Changes in community were assessed by means of a SIMPER statistical test and plotted using a non-metric multidimensional scaling ordination.
This work was carried out with the expectation that the large changes in potassium from potash to halite would cause similarly large changes in the microbial communities, but this was not observed to be the case. Very small changes in calcium concentration, however, were able to cause large changes in community composition. XRD shows that this calcium is almost exclusively calcium sulphate. The known evaporitic deposits on Mars primarily consist of sulphate minerals [11]. Determining why the calcium sulphate in Boulby Mine influences the microbial community will answer important questions about the long term survival of subsurface halophiles and the viability of martian salt deposits as a place to look for extinct or extant life.

Literature

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LIFE ON MARS: THE HABITABILITY OF EXTREMOPHILIC ARCHAEA IN SIMULATED MARTIAN CONDITIONS.

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One prerequisite for life as we know it is the access to liquid water. Recently, evidence of transient liquid brines on the surface of Mars have been presented, which could potentially harbor microbial life. Some species of archaea have adapted to thrive in high saline concentrations such as the ones theorized on Mars and are therefore of interest for astrobiological research. There are numerous other challenges to life on Mars such as osmotic pressure, high UV-radiation and desiccation. This study was aimed at simulating such environments and testing the tolerance exhibited by selected extremophiles. Analogue brines with different chemical compositions and properties were constructed to resemble soils on the surface of Mars and to test the performance of life. Investigating halophilic archaea while focusing on Halobacterium salinarum NRC-1 we were able to test its survival and growth under relevant conditions as those provided by the Curiosity Rover. Irradiation with non-ionizing UV-radiation was performed at DLR, Cologne in the “SOL2” with capacity of emulating the complete spectrum of the sun. DNA-damage was quantified by real time qPCR after increasing fluences of radiation to account for differences imposed on the cells due to seasonal- and diurnal rhythm coupled with geographical region. H. salinarum is tolerant against radiation and the tested brines had demonstrated protective effects against destructive wavelengths. Desiccation proved to be the most fatal factor to H. salinarum and as expected they survived this better at lower temperatures (-80°C) as their metabolism slows down. The results of this ongoing study highlight the relevance of halophiles as candidates for space exploration and colonization. Understanding their plasticity may also lend insights into life in the harsh conditions of early earth.

Life on the extremes:
Lichen-associated bacteria as putative candidates for astrobiological research

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Lichen symbioses (a fungus associated with an alga) represent a successful life strategy to colonize the most extreme habitats on Earth. Lichens became models in astrobiology to fathom the limits of survival under space and Martian conditions. Selected lichen species repeatedly took part in space exposure experiments on the ISS. They demonstrated high viability after exposure to real and simulated space and Mars conditions.

Recently, it has been investigated that a variety of bacteria is living on and inside lichens. The role of these bacteria as well as their possible effect on the lichen symbiosis is not known yet.
Currently, these Lichen-associated bacteria (LABs) are considered as putative co-symbiont. They have not been investigated in the context of astrobiology yet. Research with LABs will provide fascinating opportunities for astrobiological research. LABs thrive under the same extreme environmental conditions as their harbouring lichen species. Astrobiological experiments have been carried out to real and simulated space conditions. It remains still some open questions if the lichen supplies a protective microhabitat for its more or less sensible LABs, if sub-group of LABs are tolerant to extreme space conditions in their own right, or even if LABs enhance the resistance of the lichen itself. Moreover, lichens may serve as vectors for their LABs. This is particularly important for aspects of Planetary Protection. As one of the five astrobiological relevant model lichens, we decided to start the research with the model lichen Xanthoria elegans on its LABs.

The aim is to get more knowledge on the limits of viability of associated microbes of lichens considering simulated and real space conditions and on their role in association with the lichen symbiosis. The study presented intends a multiphasic experiment that contains several approaches to investigate LABs in the astrobiological context that includes identifying and isolating them and subsequently, focusing on their tolerance against non-terrestrial environmental conditions, such as high levels of UV radiation. The identification and isolation has been realized by culture-based studies, microscopic techniques and metagenomic analysis. The tolerance of LABs against simulated non-terrestrial levels of UVC-radiation was determined using culture-based studies. To conclude, the present study was implicated to improve the knowledge on astrobiological research in the context of future space exposure experiments affecting the guidelines for Planetary Protection and furthermore the hypothesis of Lithopanspermia. Additionally, new promising microorganisms for astrobiological research can be established. The investigations demonstrate

i) the potential of lichen thalline structure to provide protective effects to inhabiting microbes against the non-terrestrial stressor UVR and
ii) the possible existence of extremotolerant LABs, which may still be viable after simulated space exposure.

High Resolution Millimeter Wave Absorption Spectroscopy: from the laboratory data to the astronomical surveys

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Conventional absorption spectroscopy is still the workhorse in high-resolution rotational laboratory spectroscopy.[1] The data obtained from these kind of instruments are relevant for astronomical searches of complex molecules that represent excellent probes of the physical and chemical environments and history of the sources where they are detected.[2] Nowadays, observations performed by the Atacama Large Millimeter Array (ALMA) open up new opportunities to reveal the chemical complexity of solar systems analogues. At the same time the huge amount of data collected and the extremely rich surveys represent a challenge for the astrochemistry community. To reach this goal, the spectroscopic know-how is fundamental in recognizing typical pattern lines due to multiple internal interactions and motions that cause complicated energy level schemes, since the resulting spectra will be rather difficult to predict theoretically, mainly in the sub-mm wave region. For this reason a strong interplay between laboratory spectroscopists and observational astronomers is increasingly required to be able to unravel the experimental data.

In this talk the features and the potential of the high resolution rotational spectroscopy technique will be pointed out, providing some results on different kind of molecules characterized by complex conformational landscapes. In particular, molecular spectra of potential astronomical interest will be presented, obtained using the free jet absorption millimeter wave and the free space cell absorption sub-mm wave spectrometers working at University of Bologna.[3]