Deutsche Astrobiologische Gesellschaft e.V. (DAbG)

DAbG
Deutsche Astrobiologische Gesellschaft e.V.

4th Annual Workshop

26.-27. September 2019
Vienna, Austria
Natural History Museum

FWF
Der Wissenschaftsfonds.

frontiers in Astronomy and Space Sciences

Topics:
Space Biology, Origin of Life, Prebiotic Chemistry, Habitability, Biosignatures, Extremophiles, Exoplanets, Space Missions and Technologies

Organizing committee:
Tetyana Milojevic (Vienna), Dirk Schulze-Makuch (Berlin), Jean-Pierre de Vera (Berlin), Henry Strasdeit (Stuttgart), Dirk Wagner (Potsdam), Stefan Fox (Stuttgart)

Supported by: University of Vienna, NHM Vienna

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BOOK OF ABSTRACTS

4th Annual Workshop

of the

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26 – 27 September 2019

Naturhistorisches Museum Wien

Liebe Mitglieder der Deutschen Astrobiologischen Gesellschaft, 18.9.2019

Liebe Astrobiologen aus nah und fern,

Liebe Astrobiologie-Interessierte,

Wir, das Gründungs- und Organisationskomitee der Deutschen Astrobiologischen Gesellschaft e.V. (DAbG), heißen Sie nun auf unserem vierten Astrobiologie-Workshop, der diesmal am Naturkundemuseum in Wien stattfindet, herzlich willkommen!

Wie im letzten Jahr freuen wir uns wieder über die große Anzahl an Teilnehmern, die zu unserem Workshop erwartet werden. Das zeigt, dass die Astrobiologie mittlerweile zu einer wichtigen Größe im deutsch-sprachigen Raum geworden ist. Themenbereiche der Astrobiologie reichen vom Ursprung des Lebens in der präbiotisch-chemischen Forschung, über die Habitabilität von Planeten, die Detektierbarkeit von Leben, planetenanaloge Feldstudien in Wüsten, polaren Gebieten und Ozeanen bis hin zur Entdeckung neuer Planeten in anderen Sonnensystemen. Dabei sollten wir nicht die verschiedenen technischen und ingenieur-technischen Leistungen im deutschsprachigen Raum vergessen, die sehr häufig in inter-nationaler Kooperation zukünftige Weltraummissionen im Erdorbit, auf dem Mond, dem Mars, den Eismonden oder darüber hinaus vorbereiten.

Kleine Erfolge sind auch bzgl. der Förderung astrobiologischer Themen zu verzeichen. Es gibt nach der Helmholtz-Förderung mittlerweile kleinere Förderungen durch die DFG, das DLR, BMWi, die Humboldt-Stiftung und die Deutsche Studienstiftung, die von der Unterstützung von Konferenzen, Reisezuschüssen bis voll finanzierte Stellen reichen. Mittlerweile hat die DAbG ihre ersten Fördermitglieder sowie einen ersten Arbeitskreis („Päbiotische Chemie und chemische Evolution“). Ein Arbeitskreis „Nachwuchswissenschaftler in der DAbG“ ist in Vorbereitung. Trotz dieser Erfolge in den ersten drei Jahren der DAbG gibt es noch viel zu tun. Wir wollen erfolgreicher in der Förderung der Astrobiologie und bei Aus- und Weiterbildung in den astrobiologischen Fächern werden. Auch ist es wichtig, bei der Sichtbarkeit unserer Gesellschaft mitzuhelfen. Es geht beispielsweise um die Werbung weiterer Mitglieder und möglicher Körperschaften. Dafür sind kreative Köpfe und fleißige Hände willkommen.

An dieser Stelle möchten wir den vielen fleißigen Händen danken, die an der Organisation vor Ort und der Erstellung des Workshop-Posters und des Abstract-Buches mitgewirkt haben. Namentlich zu nennen sind insbesondere Herrn Bernhard Keppler (Universität Wien), Herr Herrn Christian Köberl (Wien, NHM), Frau Ingrid Viehberger (Wien, NHM), Frau Regina Prossinagg (Universität Wien), Herrn Emanuel Ott (Universität Wien), Frau Denise Kölbl (Universität Wien) und Frau Isabella Kazda (Universität Wien).

Wir wünschen Ihnen vielfältige fachliche Anregungen, Inspirationen und Projektideen. Dazu hilft sicher auch die Auswahl der diesjährigen Programmthemen des Workshops.

Ihr Organisations-Komitee sowie der DAbG-Vorstand

Dirk Schulze-Makuch (Vorsitzender, Berlin), Jean-Pierre de Vera (Stellvertretender Vorsitzender, Berlin), Henry Strasdeit (Stellvertretender Vorsitzender, Stuttgart), Dirk Wagner (Schatzmeister, Potsdam), Stefan Fox (Schriftführer, Stuttgart), Tetyana Milojevic (Vorsitzende, Organisationskomitee)

List of Participants:

Alessandro Airo (TU Berlin, Zentrum für Astronomie & Astrophysik)
Mihaela Albu (Graz Centre for Electron Microscopy, Graz)
Armando Alibrandi (TU Berlin, Zentrum für Astronomie & Astrophysik)
Mickaël Baqué (DLR, Institut für Planetenforschung, Berlin)
Jan Hendrik Bredehöft (Universität Bremen, Institut für Angewandte und Physikalische Chemie)
Hans Brückner (Justus Liebig-University, Gießen)
Bernd Dachwald (FH Aachen)
Jean-Pierre de Vera (DLR, Institut für Planetenforschung, Leitung und Infrastruktur, Berlin)
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Peter Weber (DLR, Köln)
Max Winkler (Max Plank Institute for Extraterrestrial Physics, Bayern)
Guenther Witzany (Biocommunication, Buermoos Austria)

Program:

4th Annual Workshop
of the Deutsche Astrobiologische Gesellschaft e.V. (DAbG)

26 – 27 September 2019

Naturhistorisches Museum Wien

Thursday 26 September			
From 9:00: Registration of participants			
10:00: Opening Session			
10:00	Opening of the Workshop and logistics	Dirk Schulze-Makuch Stefan Fox Henry Strasdeit Jean-Pierre de Vera Dirk Wagner	Members of the Executive Board of the DAbG
10:15	Welcome address	Univ.-Prof. Dr. Dr. Bernhard Keppler	Dekan der Fakultät für Chemie Universität Wien
10:20	Welcome address	Tetyana Milojevic	Universität Wien
Keynote Lecture			
Chair: Tetyana Milojevic			
10:30	Gernot Grömer	Mars Analog Missions: An Introduction to AMADEE-20	
11:10	**Coffee break**		
Session 1: Space Missions & Technologies, Planetary Field Studies			
Chair: Mickaël Baqué			
11:40	Bernd Dachwald	Key Technologies and Instrumentation for the Subsurface Exploration of Ocean Worlds	
12:00	Alessandro Airo	Strategies when searching for microbial life in the Atacama Desert, Chile	
12:20	Jean-Pierre de Vera	Planetary Simulations at DLR Berlin and in Space – Present Work and Outlook	
12:40	Cyprien Verseux	A Controlled-Atmosphere Photobioreactor for Research on Biological Life-Support	
13:00	**Lunch break**		
Session 2: Space Biology			
Chair: Oleg Kotsyurbenko			
14:30	Janosch Schirmack	Comparison of different sterilization methods on bacteria embedded in a Mars regolith analog	
14:50	Emanuel Ott	An integrative approach to extract metabolites, proteins and mRNAs from limited amount of space exposed microorganisms	

Session 3: Prebiotic Chemistry and Origin of Life		
Chair: Stefan Fox		
15:10	Christian Mayer	Molecular Evolution in a Peptide-Vesicle System
15:30	Guenther Witzany	What is Life?
15:50	Hans Brückner	Are hidden forms of life among us?
16:10	**Coffee break**	
16:30 DAbG-Mitgliederversammlung		
19:30 Conference Dinner		
Friday 27 September		
Session 4: Habitability and Biosignatures		
Chair: Denise Kölbl		
9:00	Hannes Lukas Pleyer	How Stable are the “Pigments of Life”?
9:20	Ruth-Sophie Taubner	Impact on membrane lipid composition and amino acid excretion pattern of Methanothermococcus okinawensis caused by the presence of inhibitors detected in the Enceladian plume
9:40	Mickael Baqué	Effect of Solar radiation on the Distribution of Raman Biosignatures in Salt Nodules from the Atacama Desert
10:00	Max Riekeles	Microbial Motility as a Fundamental Biosignature and Means for its Automated Detection and Analysis
10:20	Laura Jentzsch	A Potentially Brief Habitable Period on Our Moon 3.5 G.a. Years Ago
10:40	Tetyana Milojevic	Meteorite Biogeochemistry
11:00	**Coffee break**	
Session 5: Exoplanets		
Chair: Janosch Schirmack		
11:20	Jan Hendrik Bredehöft	CO2: A small ubiquitous molecule with a lot of astrochemical debate attached
11:40	Dirk Schulze-Makuch	Searching for an Exoplanet More Habitable than Earth
Session 5: Posters		
12:00	**5-min oral presentations by poster authors and Poster Session**	
13:30	**Preisverleihung**	
13:45	**Schlußworte**	

Poster Presentations:

P-01. Armando Alibrandi et al.: Experimental approaches for studying the interactions between Methanotrophs and Methane Hydrates

P-02. Christof Sager et al.: Polygonated soils in the hyper-arid Atacama Desert and their relevance to the periglacial areas on Earth and to patterned grounds on Mars

P-03. Denise Kölbl et al.: Dehydration and preservation of the encrusted extreme thermoacidophile Metallosphaera sedula grown on terrestrial and extraterrestrial materials

P-04. Hannes Lukas Pleyer: Chemical Evolution of Porphyrin-Type Cofactor Ancestors: An Overview

P-05. Max Winkler et al.: Probing RNA stability and formation in simulated prebiotic environments on the early Earth and in Space

P-06. Mihaela Albu et al.: Multiscale and Correlative Analytical Electron Microscopy of Extraterrestrial Minerals

P-07. Miriam Kuzman et al.: Mineral Formation during Thermal Treatment of Biomolecules

The posters will be on display throughout the entire Workshop.

Oral Contributions

Keynote Lecture

MARS ANALOG MISSIONS: AN INTRODUCTION TO AMADEE-20

Gernot Grömer[1], Seda Özdemir[1], Sophie Gruber[1], Stefanie Garnitschnig[1,2]

[1]Austrian Space Forum (OeWF), Innsbruck, Austria; [2]Universität Innsbruck, Institut für Ökologie

To develop the hardware, workflows and the science behind future human-robotic planetary surface missions, the Austrian Space Forum coordinates Mars analog missions, mimicking selected aspects of exploration missions to develop the protocols and procedures that will be required for human operations on Mars, and to test equipment that may be carried and used by human missions to the Mars.

The AMADEE-20 is the 13th mission of that kind with the following aims:

- Study equipment behaviour involving the simultaneous usage of instruments with the option of humans-in-the-loop (including two high-fidelity spacesuit simulators)
- Field testing of instruments and workflows pertinent to life-detection or geoscientific characterization of the test site with realistic workflows taking into account time-delayed communication, reduced bandwidth and complex decision-making framework, including a Mission Support Center with remote support teams.
- Studying the analog site as a model region for their Martian counterparts.

The test site is located in the Negev desert in southern Israel within the erosion structures of the Ramon Crater. It is not an impact crater, but a rare form of erosion structures which has a resemblance to various Mars surface features, and a variety of terrain types relevant to Mars exploration. The test site offers not only a wide range of sand and rocky surfaces combined with a broad variability in inclination and trafficability but also present the extreme conditions in temperature, low nutrients status and high levels of incident UV radiation. This combination leads to a unique adaptive place for microorganism being the more influential role in governing the surface and subsurface bio-processes, and also provides an opportunity to follow astrobiological potential of the analog research area.

AMADEE-20 will be conducted between 15Oct-15Nov2020 as the next mission. We introduce this mission and both its operation and its scientific architecture. In particular we focus on the “Exploration Cascade”, a recently developed methodology to manage multiple instruments, crews and hardware in a scientifically effective manner, supporting future Mars missions with a tactical manual for decision-making processes[1].

References

[1] Garnitschnig S. (2018), Development of a supportive method for the detection of biomarkers during future human-robotic Mars Missions- A case study to optimize the deployment modalities based on the results of the AMADEE-18 analog mission in the Dhofar region in the Sultanate of Oman. Bachelor thesis. Universität Innsbruck.

Key Technologies and Instrumentation for the Subsurface Exploration of Ocean Worlds

Bernd Dachwald[1], Stephan Ulamec[2], Frank Postberg[3], Frank Sohl[4], Jean-Pierre Paul de Vera[4], Christoph Waldmann[5], Ralph D. Lorenz[6], Kris A. Zacny[7], Hugo Hellard[4], Jens Biele[2] and Petra Rettberg[8]

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We discuss the key technologies and the instrumentation required for the subsurface exploration of ocean worlds. The focus is laid on Jupiter's moon Europa and Saturn's moon Enceladus because they have the highest potential for such missions in the near future. The exploration of their oceans requires landing on the surface, penetrating the thick ice shell with an ice-penetrating probe, and probably diving with an underwater vehicle through dozens of kilometers of water to the ocean floor, to have the chance to find life, if it exists. Technologically, such missions are extremely challenging (Dachwald et al., 2013). The required key technologies include power generation, communication, pressure resistance and radiation hardness, navigation, sterilization and cleaning, miniaturization, and autonomy. Simpler mission concepts involve impactors and penetrators or – in the case of Enceladus – plume-fly-through missions.

References

Dachwald, B., Ulamec. S. and Biele, J. (2013) Clean In Situ Subsurface Exploration of Icy Environments in the Solar System. In *Habitability of Other Planets and Satellites*, edited by J.-P. de Vera and J. Seckbach, Springer, Dordrecht, pp 367–397.

Strategies when searching for microbial life in the Atacama Desert, Chile

Airo, A.[1], Arens, F.L.[1], Schulze-Makuch, D.[1,2,3,4]

[1] Center of Astronomy & Astrophysics, Technical University Berlin, Hardenbergstr. 36 10623 Berlin, Germany. [2] GFZ German Center for Geoscience, Section Geomicrobiology, Potsdam, Germany. [3] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Department of Experimental Limnology, Stechlin, Germany. [4] School of the Environment, Washington State University, Pullman, Washington, USA.

The search for active life on Mars in near-surface environments can be guided by strategies for identifying hot-spots of active microbial communities in deserts soils on Earth. The core of the Atacama Desert, where Mars-analogous hyperarid conditions prevail, represents an ideal test-bed for developing field-reconnaissance approaches for identifying habitable micro-environments and evaluating life-detection methodologies. We here describe a variety of potential near-surface soil microhabitats located in the Yungay Valley east of Antofagasta, Chile. These generally hyperarid environments only become sporadically habitable, either after rare rain events (Schulze-Makuch et al. 2018) or during more frequent morning dew condensation events. Such episodes of increased water activity can be driven or prolonged through the presence of hygroscopic salts that undergo deliquescence, forming habitable brines (Heinz et al. 2018). For identifying such temporary micro-habitats, we characterize these environments through in-situ measurements of soil conductivity, relative humidity and temperature, as well as sedimentological and geochemical analysis in the laboratory. The presence of an active microbial community is assessed through *in-situ* measurements of soil respiration through CH_4 or CO_2 degassing measurements, the soil concentration of ATP, and 16S rDNA sequencing. Our preliminary results indicate that microbial abundance and activity does not solely correlate with soil water activity and content, but also depends on additional factors, such as soil type, salt composition, temperature and nutrient availability. Such lessons learned from searching for life in the driest deserts on Earth bear the potential to expedite the discovery of life on Mars.

References

Heinz, J.; Schirmack, J.; Airo, A.; Kounaves, S.; Schulze-Makuch, D. (2018) Enhanced Microbial Survivability in Subzero Brines; Astrobiology Vol. 18. DOI: 10.1089/ast.2017.1805.

Dirk Schulze-Makuch, Dirk Wagner, Samuel P. Kounaves, Kai Mangelsdorf, Kevin G. Devine, Jean-Pierre de Vera, Philippe Schmitt-Kopplin, Hans-Peter Grossart, Victor Parro, Martin Kaupenjohann, et al. (2018) Transitory microbial habitat in the hyperarid Atacama Desert; Proceedings of the National Academy of Sciences, 115 (11) 2670-2675; DOI: 10.1073/pnas.1714341115

Planetary Simulations at DLR Berlin and in Space – Present Work and Outlook

Jean-Pierre de Vera[1], Mickael Baqué[1], Stephen Garland[1] and Andreas Lorek[1]

[1]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany

The aim of the Astrobiological laboratories group at DLR Berlin is to combine field studies, laboratory simulation experiments and space experiments to support the search for habitable planets and life on Mars, the Icy Moons, and beyond.

Different extremophiles collected from environments with terrestrial analogy of Mars or other planetary bodies (Atacama, Antarctica, permafrost…) were tested to simulated Mars analog conditions in the DLR Mars Simulation Facility (MSF) and are planned to be tested also to laboratory simulation experiments at the new DLR-Berlin's Planetary Analog Simulation Facility (PASLAB). This new facility allows experiments which are designed to explore the limits of life and the boarders of habitability by studying further the organism's survivability and endurance to conditions expected on planets around other solar type or red dwarf stars. Also new environmental sensor systems and instruments are being developed and tested at the DLR Berlin PASLAB. The application of all these facilities and instruments might deliver in coordination with future exposure experiments such as the ESA space Experiment BioSigN (Biosignatures and habitable Niches) new results which will support future space missions, the search for habitable worlds, and the search for life in the outer Solar System and on exoplanets.

A Controlled-Atmosphere Photobioreactor for Research on Biological Life-Support

Cyprien Verseux, Jonathan Determann, Malte Duckhorn, Michael Smagin, Peter Prengel and Christiane Heinicke

Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany.

Several institutions have stated goals of sending humans to Mars in the coming decades and, while one may have doubts on the announced deadlines, such objectives are not far from the reach of today´s technologies. However, as missions get longer, providing all life-support consumables from Earth becomes unrealistic given launch costs, travel times, and risks of failure.

It has been argued that some species of diazotrophic, rock-weathering cyanobacteria could be used as a basis for life-support systems (LSS) on Mars that would rely on local resources, thereby greatly reducing the mass of consumables to be sent from Earth (Verseux et al., 2016). Fed with materials available there—atmospheric gases, water mined on site, and mineral nutrients from the regolith (Olsson-Francis and Cockell, 2010; Verseux et al., 2016)—, those cyanobacteria could be used for direct production (e.g., of oxygen and protein-rich dietary supplements), but also to support the growth of other organisms which, themselves, could perform LSS processes and bring further biotechnological capabilities (Rothschild, 2016; Verseux et al., 2016). As a simple proof-of-concept, it was shown that solutes from 25 $g \cdot l^{-1}$ of *Anabaena* sp. could support the growth of heterotrophic bacteria as efficiently as standard media (Verseux, 2018).

One of the factors that will determine the efficiency of cyanobacterium-based LSS is the behavior of cyanobacteria under non-Earth atmospheres. On the one hand, growing them under atmospheric conditions close to Mars's (low total pressure, high pCO_2, low pN_2) would simplify the system, minimize the mass of structural materials and consumables, and lower the risk of organic matter leakage (Lehto et al., 2006; Verseux et al., 2016). On the other hand, changes in gas composition and pressure affect cyanobacterial behavior. What atmospheric conditions offer the most relevant compromise remains to be found. In this talk, I will describe an atmosphere-controlled, photobioreactor-like device currently developed for such investigations at the ZARM´s newly-founded Laboratory of Applied Space Microbiology.

References

Lehto, K., Lehto, H., and Kanervo, E. (2006) Suitability of different photosynthetic organisms for an extraterrestrial biological life support system. *Research in microbiology* 157:69–76.

Olsson-Francis, K. and Cockell, C. (2010) Use of cyanobacteria for in-situ resource use in space applications. *Planetary and Space Science* 58:1279–85.

Rothschild, L. (2016) Synthetic biology meets bioprinting: enabling technologies for humans on Mars (and Earth). *Biochemical Society Transactions* 44:1158–64.

Verseux, C., Baqué, M., Lehto, K., de Vera, J.-P., Rothschild, L.J., and Billi, D. (2016) Sustainable life support on Mars – the potential roles of cyanobacteria. *International Journal of Astrobiology* 15:65–92.

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Session 2: Space Biology

Comparison of different sterilization methods on bacteria embedded in a Mars regolith analog

Janosch Schirmack[1], Dirk Schulze-Makuch[1,2,3], Samuel P. Kounaves[4,5], Miles Clark[5], Moh'D M. Amro[6], Carsten Freese[6], Ralf Moeller[7], Philippe Schmitt-Kopplin[8,9] and Jenny Uhl[8]

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Our aim was to test different sterilization methods for soil samples with the prerequisite of not significantly altering the soil's chemical composition. The underlying objective of this approach is to subsequently use the sterilized soil as a growth substrate for putative microbial life forms when inoculated with an unsterilized portion of the same soil in a life detection experiment, which could for example be used on Mars.

Escherichia coli, Deinococcus radiodurans and *Planococcus halocryophilus* were mixed with sterile and dry Mars regolith analog "JSC Mars-1A" (weight ratio: 2 parts of JSC mixed with 1 part of cell containing buffer solution). Four sterilization methods were compared:

- [1] Supercritical carbon dioxide exposure (55 °C, 75 bar, 60 min)
- [2] Rapid depressurization after pressurization (60 bar in 0.15 sec)
- [3] Irradiation with heavy ions (He ions, moderate dose of 250 Gy and Fe ions, high dose of 2000 Gy)
- [4] Autoclaving (125 °C, 1.4 bar, 25 min)

The number of viable cells was estimated with a colony forming unit (CFU) assay and compared to untreated samples. An analysis of the organic constituents (non-targeted metabolomics approach) was carried out using Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) to evaluate the effects of the different sterilization methods on the organic composition of the samples.

The CFU counts indicated that treatment with supercritical carbon dioxide [1] resulted in a reduction of the cell numbers for all tested organisms, but no complete sterilization was achieved in any of the samples. The rapid depressurization [2] only inactivate *D. radiodurans*, whereas the other two strains remained viable. The radiation treatment [3] with He ions at 250 Gy was not sufficient to inactivate any strain (maximum cell reduction to 10% of start control), while the Fe ion irradiation (2000 Gy) inactivated *E. coli* and *P. halocryophilus* (no CFUs detectable) but *D. radiodurans* cells remained viable (maximum cell reduction to 10% of start control). Only autoclaving [4] was able to inactivate all three tested strains with no viable cells detected after the treatment.

The analysis of the organic compounds with FT-ICR-MS revealed that autoclaving led to a vast increase in a variety of organic compounds with high complexity, while Fe particle irradiation resulted in a decrease of total organic compounds and a reduction in complexity. Only the depressurization method showed no changes in the composition of organics compared to the untreated control.

An integrative approach to extract metabolites, proteins and mRNAs from limited amount of space exposed microorganisms

Emanuel Ott[1], Natalie Özgen[1], Yuko Kawaguchi[2], Denise Kölbl[1], Wolfram Weckwerth[3,4], Akihiko Yamagishi[5], Tetyana Milojevic[1]*

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Astrobiology exposure experiments outside the International Space Station (ISS) often require collecting large amounts of data, although quantity of exposed microorganisms is limited. Most recently we successfully extracted metabolites, intracellular and extracellular proteins, and mRNAs from *Deinococcus* spp. exposed to Low Earth Orbit conditions for 1-3 years in frame of the Tanpopo space mission. In addition, space-returned *Deinococcus* spp. were investigated by means of scanning and transmission electron microscopy tools. Working with such samples of limited availability led to the development of an integrative extraction to maximize information output on molecular changes, which are triggered in cells exposed to the hostile environment of Low Earth orbit. Optimization of the protocol took several years, and previous versions were used for integrative extractions of proteins and metabolites from *D. radiodurans* exposed to different environmental stress conditions (Ott et al 2017, Ott et al 2019). Although the protocol was developed for bacterial material, it can be used for any kind of organism/tissue with slight adjustments in certain steps (e.g., homogenization).

References

Ott, E., Kawaguchi, Y., Kölbl, D., Chaturvedi, P., Nakagawa, K., Yamagishi, A.,Weckwerth, W., Milojevic, T. (2017) Proteometabolomic response of Deinococcus radiodurans exposed to UVC and vacuum conditions: initial studies prior to the Tanpopo space mission. *PLOS ONE* 12:e0189381.

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Molecular Evolution in a Peptide-Vesicle System

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Based on a new model of a possible origin of life, we propose an efficient and stable system undergoing structural reproduction, self-optimization, and molecular evolution. This system is being formed under realistic conditions by the interaction of two cyclic processes, one of which offers vesicles as the structural environment, with the other supplying peptides from a variety of amino acids as versatile building blocks. We demonstrate that structures growing in a combination of both cycles have the potential to support their own existence, to undergo chemical and structural evolution, and to develop unpredicted functional properties. The key mechanism is the mutual stabilization of the peptides by the vesicles and of the vesicles by the peptides together with a constant production and selection of both. The development of the proposed system over time would not only represent one of the principles of life, but could also be a model for the formation of self-evolving structures ultimately leading to the first living cell. The experiment yields clear evidence for a vesicle-induced accumulation of membrane-interacting peptide which could be identified by liquid chromatography combined with high-resolution mass spectroscopy. The peptides are then synthesized and used to reassemble the corresponding vesicle-peptide systems. The resulting functional vesicles are studied by pulsed field gradient NMR (PFG-NMR) spectroscopy. All results so far indicate that the selected peptides have an immediate effect on the vesicles, leading to (i) reduced vesicle size, (ii) increased vesicle membrane permeability, and (iii) improved thermal vesicle stability.

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Session 3: Prebiotic Chemistry and Origin of Life

What is Life?

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What is life?

When Erwin Schroedinger asked this question, for him the answer was clear „Life is Physics and Chemistry“. But he could not know the paradigmatic changes in knowledge through the comeback of virology and RNA-world hypothesis. Now we know that RNA-groups that self-replicate predated cellular life and still regulate nearly all cellular processes such as replication, transcription, translation, immunity and repair. Additionaly we found that viruses are the most abundant living agents on this planet that introduce RNA-regulations in all life forms via infection events and remain as usefull regulatory tools for cellular needs, such as mobile genetic elements. Schroedingers definition needs a crucial update now: Life is an inherently social process based on communicating RNA networks, in which viruses and cells continuously interact and complementary depend on each other.

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Session 3: Prebiotic Chemistry and Origin of Life

Are hidden forms of life among us?

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It has been hypothesized that cryptic or weird forms of life, based on non-proteinogenic amino acids, in particular **D-amino acids** and/or **α-dialkyl α-amino acids** such as α-aminoisobutyric acid (**Aib,** 2-methylalanine), may occur somewhere on planet Earth (Davies et al., 2009). Therefore, detection of such molecular markers should be indicative for alien forms of life representing a so-called 'shadow biosphere'.

However, natural product chemistry clearly indicates that this point of view is obsolete. It is obvious that a large number of various **D-amino acids** are constitutents of the cell wall and cytoplasm of bacteria. D-amino acids are also found in in the free or peptide-bound state in numerous secondary metabolites of microorganisms and plants, but also occur in tissues and body fluids of aquatic and terrestrial vertebrates and invertebrates (Friedman, 2010).

In order to encompass all bioactive natural peptides containing **α-dialkyl α-amino acids**, the 'Pept**aib**iotics Database' became established (Stoppacher et al., 2013). In 2017, this database already hosted about 1430 sequences of non-ribosomally biosynthesized fungal peptides containing the eponymous **Aib** and, frequently, D- or L-**i**so**va**line (**Iva**, 2-ethylalanine), or even both enantiomers of Iva in the same molecule (Brückner et al., 2009; 2019).

Therefore, the detection of these non-coded amino acids in the free or peptide-bound form must not be considered convincing evidence for 'alien' or 'weird' forms of life.

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How Stable are the "Pigments of Life"?

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Biological porphyrin-type cofactors (PTCs) occur ubiquitously on modern Earth. They have been called the "pigments of life" because of their intense colors and their importance for organisms (Battersby, 2000). The PTCs contain various metal centers, such as $Fe^{2+/3+}$, Mg^{2+}, Co^{3+}, and Ni^{2+}. Most obvious is the presence of the Mg-containing chlorophylls in all green plants. Of equal importance are the Fe-containing hemes which are involved in cellular respiration of organisms from all kingdoms of life.
More than one-billion-year-old PTCs were found in marine blackshales (Gueneli *et al.*, 2018). This finding proves the long evolutionary history of porphyrins and their exceptional stability over geological time. Because of their ubiquity, easy detectability and high stability, porphyrins have been suggested as biosignature candidates (Suo *et al.*, 2007). However, porphyrins and their metal complexes can also be of non-biological origin (Fox and Strasdeit, 2013; Pleyer *et al.*, 2018), *i.e.*, they can be "false-positive" biosignatures. Thus, like most other molecular biosignatures, they are not "ideal" (Fox and Strasdeit, 2017). This does not mean that PTCs should be rejected as potential biosignatures, but their advantages (for example, their stability) and disadvantages must be carefully scrutinized.
Despite the fact that stability is a crucial property of any biosignature, there is little data on the stability of porphyrins in an astrobiological context. In the search for porphyrins outside Earth, it is important to identify the locations where porphyrins can survive and where they cannot. Against this background we recently investigated the stability of a model PTC, namely the iron porphyrin chlorido(octaethyl-porphyrinato)iron(III) [FeCl(oep)], against various acids, bases, and oxidizing agents. Oxidizing agents, such as magnesium perchlorate, were chosen in view of the presence of oxidants in the martian regolith. In addition, the temperature stability of [FeCl(oep)] was studied in three different atmospheres: air, pure nitrogen, and pure carbon dioxide. The results will be presented and their relevance to PTCs as biosignatures discussed. The suitability of PTCs as biosignatures in general will also be addressed.

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Impact on membrane lipid composition and amino acid excretion pattern of *Methanothermococcus okinawensis* caused by the presence of inhibitors detected in the Enceladian plume

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Amino acids and lipids are among the molecules that are assumed to serve as biomarkers in the search for extraterrestrial life on other planets and moons. One potential habitat for life could be Saturn's icy moon Enceladus. Despite its small size, the moon is known for its spectacular plume and its large subsurface ocean (Porco et al., 2006; Thomas et al., 2016). Besides water (H_2O), molecular hydrogen (H_2), carbon dioxide (CO_2), ammonia (NH_3), and methane (CH_4) were detected in the Enceladian plume (Waite et al., 2017). In addition to these compounds, also traces of potential inhibitors for life-as-we-know-it like formaldehyde (CH_2O) and methanol (CH_3OH) were found (Waite et al., 2009).

We examined the influence of CH_2O, CH_3OH, and ammonium (NH_4^+) on growth, lipid distribution and production, and amino acid excretion patterns of the methanogenic archaeon *Methanothermococcus okinawensis*. In a previous study, we showed that this methanogen thrives under putative Enceladus-like conditions (Taubner et al., 2018). Here we document the variability of the membrane lipid composition and amino acids excretion patterns as a function of concentration and ratio of these inhibitors in the growth medium. While CH_3OH did not show a significant impact on growth, lipid or amino acid production rates, $NH_4^+$and CH_2O strongly affected the lipid composition and amino acid excretion.

These findings are key to understand the eco-physiology of methanogens on Earth and have implications for the use of biomarkers as possible signs of extraterrestrial life during future space missions in the Solar System.

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Effect of Solar radiation on the Distribution of Raman Biosignatures in Salt Nodules from the Atacama Desert

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The next two rover missions to Mars, ESA/Roscosmos's ExoMars2020 and NASA's Mars2020, will carry for the first time Raman spectrometers potentially able to dectect traces of past or present life. To support and interpret future spectroscopic data correctly a better understanding of potential habitable environments and putative biosignatures, using analogue environments such as the Atacama Desert, is of paramount importance. In the Atacama Desert, one of the driest places on Earth, life has developed adaptive strategies to decreasing amounts of water: from refuges inside or below rocks as endoliths or hypoliths to inside salts in hygroscopic niches (Davila & Schulze-Makuch, 2016). In the hyperarid core one of the last refuges for life are inside salt crusts using deliquescence as a water source or being in the subsurface waiting for transitory episodes of increased moisture (Schulze-Makuch et al., 2018). These adaptive strategies might also apply to putative Martian life which endured a transition from a water rich past to the very harsh surface conditions of the present giving us clues on where to best look for traces of life on the Red Planet. Salt crusts and salt nodules are particularly interesting targets in this regard because they reside on or very near the surface and are thus easily accessible to future robotic missions. In the Atacama, salt nodules have been shown to host photosynthetic organisms containing easily identifiable pigments by Raman spectroscopy such as carotenoids and scytonemin (Vítek et al., 2014). One of the most damaging factors for life and its remains, both in the Atacama and on Mars, is solar radiation. To investigate the spatial distribution of potential Raman signatures in micro-niches we generated georeferenced 3D-reconstructions of the sampling areas using photogrammetry techniques and plotted the dose received according to the nodules' orientation. We then analysed salt nodule along dry cut north-south thick sections using Raman mapping to infer any relations between the amount of light received and the presence of detectable signal. Preliminary data show an increased presence of carotenoids, scytonemin, and other biomolecules signals on the nodules oriented towards the south, which are the-more-protected sections of the nodules.

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Microbial Motility as a Fundamental Biosignature and Means for its Automated Detection and Analysis

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Microbial motility is ubiquitous in all three domains of life and is commonly induced by environmental conditions (Madigan, et al., 2016, p.58). The locomotive behavior at the smallest scale of life has since van Leeuwenhoek, the father of microbiology, been used as a biosignature and was the basis of the initial classification of motile microorganisms as “little animals”. Future missions to potentially habitable places in the solar system require biochemistry-independent biosignatures for detecting potentially alien life forms; ‘motility’ is an ideal candidate in this context (Nadeu et al., 2016).

Specific cell dyes are often needed to distinguish the very small organisms from non-living particles, which leads to higher demands upon the detection instrument. Analysis of still images can easily lead to misidentification of putative microorganisms; however, the use of time-lapsed imaging provides the opportunity of high confidence life detection if a microbe exhibits motility.

Many microbes move in different ways under specific conditions. This means that movement can not only be exploited to detect life but may be used also to distinguish the species. Methods for detecting microbial motility automatically can be used for space missions as well as in the medical field using appropriate optical devices in combination with machine learning algorithms for automated identification of putative pathogens.

The specific advantages and disadvantages of different microscope types for space missions are elucidated, as well as an overview of the specific image processing algorithms and supervised machine learning algorithms such as regression learner and classification learner currently used by us for the analysis of microbial motility.

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A Potentially Brief Habitable Period on Our Moon 3.5 G.a. Years Ago

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Our Moon has no significant atmosphere, no liquid water on its surface, no polymeric chemistry, and is certainly uninhabitable and lifeless today. However, for two brief periods, shortly after the formation of the Moon and again at about 3.5 billion years ago, there might have been enough water to create temporary habitable conditions on our Moon (Schulze-Makuch and Crawford, 2018).
This second time period is related to major outgassing events that have resulted in an atmospheric pressure of about 10 mbar (Needham and Kring, 2017), meaning that a transient atmosphere with higher pressures than the current Martian atmosphere has prevailed for millions of years. Furthermore, the early Moon might have had a magnetic field (Hood, 2011), protecting its surface from solar and cosmic radiation. At this time, life on Earth had already evolved and a transfer of organic material or microbial life from Earth to the Moon through impacts is conceivable.
In order to evaluate the early Moon regarding its habitability, we conducted experiments in an Early Lunar Environmental Simulation Chamber. Different bacterial strains mixed within lunar soil simulant were exposed to an atmosphere consisting of mainly CO and small amounts of H_2S for different time intervals under a pressure of 10 mbar. While the cyanobacterial strain *Microcoleus chthonoplastes* did not survive the exposure, the spore-forming *Bacillus subtilis* survived almost unimpaired in both experimental runs, as determined by CFU's. Also, the cyanobacterial strain *Chroococcidiopsis 029* survived the early Lunar conditions, which could be additionally confirmed by viability tests such as INT staining and PCR-PAM assays.
Based on those results, life could at least be able to maintain viability under the early Lunar environmental conditions, however, any metabolic activity during the experiments has not yet been proven and will be tested for in future experiments.

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Meteorite Biogeochemistry

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Meteorites are “space probes” available on Earth, while returned extraterrestrial mineralogical samples are not yet accessible. Meteorites may have delivered a variety of essential compounds facilitating the evolution of life, as we know it on Earth. Moreover, assessing the biogenicity based on extraterrestrial materials provides a valuable source of information for exploring the extraterrestrial bioinorganic chemistry that potentially might have occurred in the Solar System. We explore the microbial-meteorite redox interactions, highlighting the possibility of bioprocessing of extraterrestrial metal resources and revealing specific microbial fingerprints left on extraterrestrial material. Chemical specific analysis of meteorite-microbial interface at nm-scale spatial resolution allowed us to trace the trafficking of meteorite inorganic constituents into a microbial cell and investigate iron redox behavior. Combining several analytical spectroscopy techniques with transmission electron microscopy analysis, we provide a set of biogeochemical fingerprints left upon growth of metal-oxidizing extreme thermoacidophile *Metallosphaera sedula* on genuine meteorite materials. Our investigations validate the ability of *M. sedula* to perform the biotransformation of meteorite minerals, unravel microbial fingerprints left on meteorite materials, and provide the next step towards an understanding of meteorite biogeochemistry. Our findings will serve in defining mineralogical and morphological criteria for the identification of metal-containing microfossils.

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CO_2: A small ubiquitous molecule with a lot of astrochemical debate attached

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Carbon dioxide (CO_2) is the second or third most abundant molecule in icy mantles found around dust grains in interstellar and circumstellar dust clouds (after water and possibly carbon monoxide) (Hama and Watanabe 2013). It has been remotely observed in dense clouds, young stellar objects (Ehrenfreund and Charnley 2000) and comet Hale-Bopp (Irvine *et al.* 2000), and its abundance in the gas phase of comet 67P has even been measured *in situ* (Goesmann *et al.* 2015). One should assume that the origin of a molecule this abundant has been determined to a fairly high degree of scientific consensus. Surprisingy, this is not the case. It is generally agreed upon that the most important precursor to CO_2 is carbon monoxide (CO), and that it is very probably oxidized by water (H_2O). The investigation of the exact mechanism by which CO is oxidized has, however, turned up conflicting and sometimes contradictory reports by numerous authors, depending on the experimental techniques used. The most contentious point is the role that the intermediate radical $HOCO^{\bullet}$ plays. In some studies, it has confidently been declared the intermediate in a reaction leading to CO_2 (Milligan and Jacox 1971), while in other studies its presence could not be confirmed at all (Hudson and Moore 1999). Further complicating the matter are theoretical studies that predict that $HOCO^{\bullet}$ should quickly be stabilized in a water matrix, making its conversion to CO_2 energetically unfeasible (Arasa *et al.* 2013). We have investigated the formation of CO_2, along with a number of side products, during electron irradiation of mixed CO/H_2O ices. Our experimental techniques allow us to identify and isolate individual reaction routes by electron energy. This allows us to link intermediates to specific reation products even in concurring reactions. In the study we find that $HOCO^{\bullet}$ is indeed a very important intermediate in the reaction between H_2O and CO, but is not an intermediate leading to the formation of CO_2 (Schmidt *et al.* 2019). It would appear that even in chemically very simple reaction mixtures like CO and H_2O, several side products and different reaction channels with different intermediates have to be considered.

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Searching for an Exoplanet More Habitable than Earth

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The fact that Earth is teeming with life makes it appear odd to ask whether there could be other planets in our galaxy that are even more suitable for life (Heller and Armstrong 2014). The neglect of this possible class of superhabitable planets, however, could be considered anthropocentric and geocentric and would run contrary to the Copernican Principle. Surely, Earth is habitable to a very high degree given its rich and complex biota. Nevertheless, we argue that there are regions in the astrophysical parameter space of star-planet systems that could allow for planets to be even more habitable than Earth. We propose that planets could offer more benign environments for life to form and flourish if as many of the following conditions as possible are met: (1) the planet is in orbit around a K dwarf star, (2) it is about 5 to 8 billion years old, (3) it is about 1.5 to 2 times more massive than Earth and about 20% larger than Earth, (4) the planet has a mean surface temperature about 5°C higher than on Earth, (5) it has a moist atmosphere with 30% O_2 levels, the rest mostly inert gases (e.g. N_2), (6) it has scattered land/water distributed with lots of shallow water areas and archipelagos, (7) it has a large moon (1-10% of the planetary mass) at moderate distance (10 – 100 planetary radii), and (8) the planet has plate tectonics or a similar geological/geochemical recycling mechanism. Some of these parameter choices are astrophysically motivated, while others are based on the natural history of our planet, which experienced time periods of varying habitability (Schulze-Makuch and Irwin 2018). Some of the conditions (1)-(8) are far from being observationally testable on planets outside the solar system, e.g. the question of surface water and land distribution. That said, we can distill a short list of top contenders among the over 4000 exoplanets known today that could be candidates for a superhabitable planet. In fact, we argue that in search for extrasolar life these planets deserve higher priority for follow-up observations than the most Earth-like planets.

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Poster Presentations

P-01

Experimental approaches for studying the interactions between Methanotrophs and Methane Hydrates

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Methane Hydrates, crystalline non-stoichiometric compounds composed by methane and water, are estimated to hold around 5000 Gt of methane carbon on Earth (Boswell and Collett, 2011). Methane hydrates are thought to exist also on other planetary bodies such as Mars, Titan, or Triton and particularly on the ocean floor of the icy moons such as Europa or Enceladus; (Mousis *et al.*, 2015).
Methylovolum psychrotolerans sph1 is a recently isolated methanotroph capable of using methane and methanol as source of energy isolated from a cold methane seep in a floodplain in western Siberia (Oshkin *et al.*, 2016). Hence, *M. psychrotolerans* is a suitable model organism to investigate methane hydrate microbe interactions, due to its ability to grow at low temperatures (from 2°C); conditions that allow hydrate stability at lower pressures.
To our knowledge no *in-vitro* growth experiments involving methanotrophs consuming methane hydrates have been conducted.
We here propose to conduct experiments using high-pressure vessels in which methane hydrate is mixed with sediment material and *M. psychrotolerans* cells. The organism will be added before the formation of the hydrate-sediment mixture and the pressure within the vessels will be slowly increased to values providing hydrate stability and avoiding a pressure shock of the microorganism. The internal pressure of the vessel will be brought to a point where methane hydrate is stable, but carbon dioxide hydrate is not. This will allow the CO_2 produced by the microorganism to escape from the hydrate lattice into the headspace of the high-pressure vessel. This headspace gas will be used as a proxy to monitor bacterial activity.
The aim is to investigate the adaptation of *M. psychrotolerans* to grow on the hydrate surface.
Experiments with temperature shifts will be performed creating instability in the hydrate to observe the consumption response to a rapid release of methane.
Understanding the habitability of methane hydrates could give us valuable insights into how life might have adapted in extra-terrestrial environments and how methanotrophs on Earth could mitigate the sudden methane release caused by global warming.

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P-02

Polygonated soils in the hyper-arid Atacama Desert and their relevance to the periglacial areas on Earth and to patterned grounds on Mars

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Patterned grounds hold much information on climatic conditions and soil properties, but thus far they have only been investigated in terrestrial periglacial regions and on Mars. The study presented here examines the formation processes of patterned grounds in the hyperarid Atacama Desert. A comparative study of all three study areas not only helps to understand ongoing soil processes in the Atacama Desert and periglacial regions, but also provides insights in potential analogous processes occurring on Mars. The repetitive geometrical forms of these natural soil patterns can appear on the surface as circles, stripes or polygons. Their formation in periglacial regions which are characterized by the presence of permafrost, is generally controlled by a process termed 'frost heave' through repetitive freeze-thawing of ground water, accompanied by the deformation of soil. However, ground ice is lacking in the Atacama Desert but instead the soils are rich in various salt assemblages and show a high clay content, which can also lead to ground deformation due to repetitive temperature variations and rare rain events. Therefore, we assume that processes such as swell-, thermal- and haloturbation, which show similarities to frost heave, contribute to patterned ground formation. In order to identify the underlying formation process, various soil characteristics (e.g. salt content, mineralogy, temperature profiles) and morphometric parameters (e.g. size, orientation, shape) of various patterned grounds will be determined through drone-based 3D-reconstruction of the patterned grounds, as well as geochemical and sedimentological soil analyses. Our inital results show that the mainly orthogonal polygons are separated by uncemented sandwedges up to 1 m depth that are clearly visible at the surface. The diameter of the high-centered polygons ranges from ~ 0.5 m to 7 m. Our inital results indicate that the formation of the polygons investigated in this study is related to the presence of large quantities of soluble salts (mainly sodium chloride) in the near subsurface (from 15 cm depth) that contributes to a cementation of the ground. In contrast, the soil of the Yungay site ~ 500 m further south, investigated by Schulze-Makuch et al. (2018), is characterized by a polygonal cracked sulfate hardpan composed of gypsum and anhydrite, while halite near the surface is lacking. Furthermore, polygonal structures at the Yungay site are hardly visible from the surface and the sand wedges are of lower depth and width in comparison to the halite polygons, which indicates an important role of sodium chloride for patterned ground formation.

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P-03

Dehydration and preservation of the encrusted extreme thermoacidophile *Metallosphaera sedula* grown on terrestrial and extraterrestrial materials

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Microbial and mineral co-evolution throughout Earth's history has shaped life as we know it on our planet. Microbe-mediated biomineralization implies the formation and deposition of a newly appearing mineral layer by a microorganism frequently utilizing its unique metabolic capacities. Compared to bacteria, biomineralization and fossilization of archaeal strains have been rarely explored processes with only a few reports existing. The extreme thermoacidophilic archaeon *Metallosphaera sedula* is a metal-mobilizing archaeon able to catalyze redox transformations of minerals while growing chemolithoautotrophically on a variety of metal-bearing substrates (Auernik and Kelly, 2008). Investigating the interactions of this extreme metallophilic microorganism with different mineral substrates of terrestrial and extraterrestrial origin, we have observed its selective cell surface biomineralization and preservation of cellular integrity under the dehydration conditions (Kölbl et al., 2017). When grown on certain mineral materials, *e.g.*, tungsten bearing ores, meteorite, cells of *M. sedula* are capable of forming an encrusted S-layer of various metal content, which strikingly preserves cellular morphology and integrity after dehydration, and therefore can potentially serve as a microbial fingerprint to be looked for in the geological record. Surprisingly, no preserved cells after the dehydration process could be detected when *M. sedula* is grown on synthetic extraterrestrial materials such as Martian Regolith Simulants. Preservation of *M. sedula* cells under the desiccation conditions described in the present study appears to be a discriminatory process, which depends on the nature and content of the mineral source used for growth of this metallophilic archaeon. The thorough investigation of these biogeochemical signals can help us to gain a deeper insight into microbial-mineral co-evolution on Earth over geological timescales and to enhance our knowledge of biosignatures for a search of life on other celestial bodies.

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P-04

Chemical Evolution of Porphyrin-Type Cofactor Ancestors: An Overview

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Porphyrin-type cofactors (PTCs) can be found everywhere in the living world. The two most prominent examples are the chlorophylls (magnesium porphyrin complexes) and the hemes (iron porphyrin complexes), which are essential for photosynthesis and electron transfer, respectively. Despite the complex structure of the porphyrin macrocycle, PTC ancestors may already have formed on the prebiotic Earth. In fact, some relevant abiotic syntheses of free-base porphyrins, including hydrophobic, amphiphilic and hydrophilic ones, are known (Lindsey *et al.*, 2009; Fox and Strasdeit, 2013; Alexy *et al.*, 2015). Furthermore, metalation of porphyrins was achieved under simulated prebiotic conditions (Soares *et al.*, 2013; Pleyer *et al.*, 2018). Thus, simple PTC ancestors could have been available to abiotic protometabolisms or very early life forms on the young Earth. For these systems, the metalloporphyrins may have been versatile components offering, for example, protection against ultraviolet radiation and the capability of one-electron transfer. In addition, metalloporphyrins could have been involved in organic redox transformations and as photosensitizers in photochemical processes.

The different abiotic porphyrin syntheses and metalation reactions of possible prebiotic relevance will be presented. The possible role of abiotically formed PTC ancestors in the origin of life—particularly, in hypothetical protometabolisms—and in early organisms will be discussed.

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P-05

Probing RNA stability and formation in simulated prebiotic environments on the early Earth and in Space

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Complex organic molecules like nucleobases (Pearce and Pudritz, 2015), amino acids (Lai et al, 2019) and fatty acids (Cobb and Pudritz, 2014) were found in many meteorites. Recent studies of the comet 67P/Churyumov-Gerasimenko were able to identify the amino acid glycine in a comet for the first time (Altwegg et al., 2016). Comets and meteorites could be an important sources of prebiotic molecules for the early Earth. In our labs, we aim to uncover the role of these extraterrestrial materials in the synthesis and stability of RNA. The facilities at the CASICE laboratory will allow us to expose RNA and its building blocks to a wide range of conditions such as low temperatures (down to 10 K), different atmospheres and solvents as well as to UV radiation. We use spectroscopic techniques to investigate the reaction of nucleobases and nucleotides in these different stresses, which simulate conditions on cometary bodies and of environments plausible for the early Earth. The higher UV flux of the young sun could have influenced the selection for canonical nucleobases (Cataldo, 2018; Fornaro et al., 2013). To investigate this question we studied the photosensitivity of uracil, uridine, adenine, adenosine, cytidine and cytosine. The samples were irradiated with a UV source and Raman spectra were recorded to survey photolysis. Uracil and uridine showed the highest photosensitivity. Moreover, the nucleotide uridine showed a higher UV resistance compared to its corresponding nucleobase uracil, which suggests photoselection as a plausible contributor to the driving force towards a rise in chemical complexity.

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P-06

Multiscale and Correlative Analytical Electron Microscopy of Extraterrestrial Minerals

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Analytical scanning and transmission electron microscopy investigations from mm- down to nm- size have proven to be an essential tool for microstructure investigations of extraterrestrial minerals. Therefore, the new correlative microscopic method RISE (Raman Imaging and Scanning Electron microscope), a seamless combination of two techniques, offers the possibility of high resolution imaging by the scanning electron microscope Sigma 300 VP (Zeiss, Oberkochen, Germany) and chemical analysis with the attached Raman microscope from WITec (Ulm, Germany). Moreover, the electron microscope is equipped with a modern silicon drift detector from Oxford (UK) for energy dispersive X-ray spectroscopy (EDX) that enables spectra and mappings in a comparatively short time and rounds up the correlative investigations. Furthermore, energy filtered transmission electron microscopy (EFTEM) images as well as high-resolution high angular annular dark field imaging (HAADF) acquired in scanning mode, together with electron energy loss (EELS) and X-ray (EDX) spectroscopy, provide information about the structure and chemical composition at nanometer-scale.

Extraterrestrial minerals contain mostly Fe, Co and Ni but also other elements like N, O, S, P, Al, Si, V, Cu, Zn, Mn, Cr, Ir and furthermore rare earths. Figure 1 shows EDXS maps of a large area from a fragment of the Chelyabinsk meteor. Usually, to avoid charging effects, a coating (C or Au) needs to be performed prior SEM investigations. However, in this particular case, the preparation of the sample surface needs to be free for additional Raman spectroscopy from the same area. Thus, nitrogen was used as imaging gas in the variable pressure (VP) mode. Figure 2 presents SEM, STEM and EFTEM micrographs from the Seymchan meteorite. The inset on Figure 2a depicts the metallic area from which a lamella was prepared by focused ion beam (FIB). Needle-like and core-shell Ni-rich particles of about 100 nm have been studied by EDX spectroscopy. We found concentrations of about 54.2 at% for Fe, 39.4 at% for Ni, 6.2 at% for Co and 0.2 at% for O, but no phosphorus.

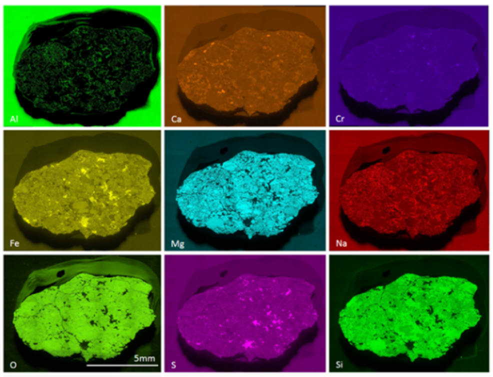

Fig. 1. Correlated large area EDXS maps from a fragment of the Chelyabinsk meteorite.

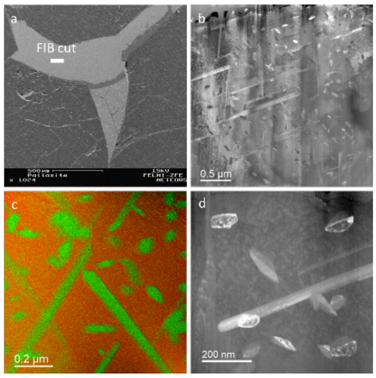

Fig. 2. a) SEM and b) STEM image from the Seymchan meteorite; c) EFTEM composed image: red-Fe and green-Ni; d) STEM HAADF image.

This work was supported by the projects "HRSM-Projekt ELMINet Graz - Korrelative Elektronenmikroskopie in den Biowissenschaften" and “Innovative Materialcharakterisierung", SP2016-002-006, which is part of "ACR Strategisches Projektprogramm 2016" of the Austrian Cooperative Research (ACR)

P-07

Mineral Formation during Thermal Treatment of Biomolecules

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In the early history of Mars, the conditions on the planet resembled those on the young Earth. Hence, the possibility for simple life to emerge and evolve on the red planet exists (Westall *et al.*, 2013). Even if the martian organisms could not survive the increasingly harsh conditions on the planet, their remains might still be present near the martian surface. In 2020, ESA's ExoMars and NASA's Mars 2020 missions will start their flights to Mars. Both aim to land a rover on the Martian surface and will search for biosignatures (Vago *et al.*, 2017; Williford *et al.*, 2018).
But do we know what we are looking for? Which molecules, if found on Mars, could serve as unambiguous biomarkers (Fox and Strasdeit, 2017)? Molecules of biological origin decompose differently under different conditions, whereby the mineral composition of the hosting rock can influence the decomposition process (see, for example, Dalai *et al.*, 2017). As it is known that Mars had strong volcanic activity, we performed thermolysis experiments in the laboratory to help answering these questions. We used different biomolecules and varied the mineral matrix in which these molecules were heated to cover different minerals found on Mars (Ehlmann and Edwards, 2014). In our experiments, oxygen was excluded by using a pure nitrogen atmosphere. The thermal residues have been analyzed by infrared spectroscopy and X-ray powder diffraction.
The heating process led to different decomposition products depending on the chosen matrix. Especially lecithine, a phospholipid and common membrane component of cells, gave surprising results which could be interesting for future Mars missions. The details will be presented.

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