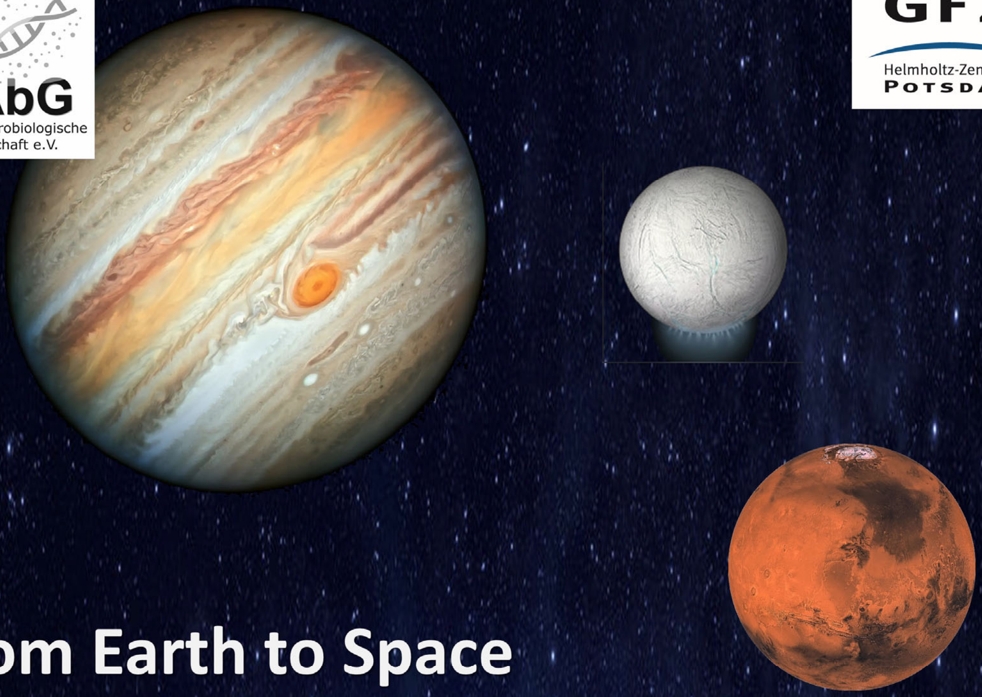
DAbG
Deutsche Astrobiologische Gesellschaft e.V.

GFZ
Helmholtz-Zentrum
Potsdam



From Earth to Space

8th Annual Workshop of the Deutsche Astrobiologische Gesellschaft e.V. (DAbG)

16 – 18 September 2024
German Research Center for Geosciences (GFZ), Potsdam

Topics – *Earth Analogues, Habitability, Extremophiles, Biosignatures, Prebiotic Chemistry, Origin of Life, Exoplanets, Space Missions & Technologies*

www.astrobiologie.de

BOOK OF ABSTRACTS

8th Annual Workshop

of the

Deutsche Astrobiologische Gesellschaft e.V. (DAbG)

16 – 18 September 2024

Deutsches GeoForschungsZentrum (GFZ) Potsdam

Liebe Mitglieder der Deutschen Astrobiologischen Gesellschaft,
Liebe Astrobiologinnen und Astrobiologen aus nah und fern,
Liebe Astrobiologie-Interessierte,

Wir, der Vorstand der Deutschen Astrobiologischen Gesellschaft e.V. (DAbG) und das Organisationskomitee, heißen Sie auf unserem achten Astrobiologie-Workshop, der diesmal am Deutschen Geoforschungszentrum Potsdam stattfindet, herzlich willkommen!
Die Astrobiologie ist mittlerweile zu einer wichtigen Größe im deutsch-sprachigen Raum geworden, und wir denken, dass dieser Workshop auch dazu beiträgt, damit dies so bleibt und wir noch mehr Zulauf und Interesse wecken. Themenbereiche der Astrobiologie reichen vom Ursprung des Lebens in der Präbiotik, über die Habitabilität von Planeten, die Detektierbarkeit von Leben, planetenanaloge Feldstudien in Wüsten, polaren Gebieten, Ozeanen und im Erdorbit bis hin zur Entdeckung neuer Planeten in anderen Sonnensystemen. Zu den wissenschaftlichen Themengebieten kommen die technischen und ingenieur-technischen Errungenschaften im deutschsprachigen Raum hinzu, die sehr häufig in internationaler Kooperation, speziell mit der EANA oder der ESA stattfinden.
Inzwischen ist unsere Webseite professionalisiert, sodass nun unter anderem eine englische Version zur Verfügung steht. Wir haben eine Partnerschaft mit dem Spanischen Netzwerk für Planetologie and Astrobiologie (REDESPA) und mehrere Arbeitskreise etabliert. In einem Arbeitskreis (Eismonde und Ozeanwelten) haben wir sogar inzwischen die erste Veröffentlichung in einem Fachjournal über die Arbeit der DAbG veröffentlicht. Auf unserer Webseite, sind Stellenanzeigen und Ankündigungen von Konferenzen und anderen wichtigen Veranstaltungen abrufbar. Natürlich gibt es immer noch viel zu tun. Wir wollen erfolgreicher in der Förderung der Astrobiologie und bei Aus- und Weiterbildung in den astrobiologischen Fächern werden, die Sichtbarkeit unserer Gesellschaft erhöhen, und auch unsere Mitgliederzahl steigern. Wir sind für jedes kreative Engagement in dieser Hinsicht dankbar.
An dieser Stelle möchten sich die Mitglieder des Vorstandes ganz besonders bei Dirk Wagner vom Deutschen Geoforschungszentrum Potsdam für die Organisation des diesjährigen Workshops bedanken. Solch eine Organisation kostet immer sehr viel Arbeit und die Initiative unserer Mitglieder ist daher sehr geschätzt.
Wir wünschen Ihnen viel Inspiration und Projektideen während des Workshops und dass wir uns alle besser kennenlernen!

Der DAbG-Vorstand und der Vorsitzende des Organisationskomitees (27.08.2024):

Dirk Schulze-Makuch (Vorsitzender, Berlin), Jean-Pierre de Vera (Stellvertretender Vorsitzender, Köln), Christian Mayer (Stellvertretender Vorsitzender, Duisburg-Essen), Dirk Wagner (Schatzmeister und Vorsitzender, Organisationskomitee, Potsdam), Janosch Schirmack (Schriftführer, Berlin)

List of Participants:

Felix Arens (TU Berlin, Zentrum für Astronomie & Astrophysik)
Timo Babel (Heinrich-Heine-Universität, Düsseldorf)
Mickaël Baqué (DLR, Institut für Planetenforschung, Berlin)
Jan Bredehöft (Universität Bremen, Institut für Angewandte und Physikalische Chemie)
Hans Brückner (University of Giessen)
Alejandra Cabrera (Universität Hamburg)
Kuhan Chandru (Universität Duisburg-Essen, Physikalische Chemie, Essen)
Marie Dannenmann (Freie Universität Berlin/Institute of Geological Sciences/Planetary Sciences and Remote Sensing)
Jean-Pierre de Vera (DLR, MUSC, Raumflugbetrieb und Astronautentraining, Köln)
Ulrich Dopatka (Universität Bern, former institution, retired)
Berke Duarte dos Santos (Instituto Superior Técnico, Lisbon, Portugal)
Florian-Carlo Fischer (TU Berlin, Zentrum für Astronomie & Astrophysik)
Jacob Heinz (TU Berlin, Zentrum für Astronomie & Astrophysik)
Philipp Henn (Ruhr Universität Bochum)
Bernd Henschenmacher German Federal Office for Radiation Protection (BfS)
Lucía Hortal Sánchez (Freie Universität Berlin)
Tom Janetzek (Deutsches GeoForschungsZentrum, GFZ)
Osman Can Kandemiroglu (Universität Bremen)
Nozair Khawaja (Institute of Space Systems, University of Stuttgart)
Fabian Klenner (University of Washington)
Ralf Liebermann (Potsdam Institute for Climate Impact Research, former institution)
Daniel Maurer (Deutsches Elektronen-Synchrotron DESY, Zeuthen)
Christian Mayer (Universität Duisburg-Essen, Physikalische Chemie, Essen)
Maryse Napoleoni (Freie Universität Berlin)
Lena Noack (Freie Universität Berlin)
Shivani Nundoo (TU Berlin, Zentrum für Astronomie & Astrophysik)
Frank Postberg (Freie Universität Berlin)
Max Riekeles (TU Berlin, Zentrum für Astronomie & Astrophysik)
Janosch Schirmack (TU Berlin, Zentrum für Astronomie & Astrophysik)
Dirk Schulze-Makuch (TU Berlin, Zentrum für Astronomie & Astrophysik)
Frank Sohl (DLR, Institut für Planetenforschung)
Alexander Thamm (Freie Universität Berlin)
Jorge Vago (European Space Agency's technical centre, ESTEC)
Iva Vilovic (TU Berlin, Zentrum für Astronomie & Astrophysik)
Dirk Wagner (Deutsches GeoForschungsZentrum, GFZ)

Program:

8th Annual Workshop
of the Deutsche Astrobiologische Gesellschaft e.V. (DAbG)

16 – 18 September 2024

Deutsches GeoForschungsZentrum (GFZ)

Monday 16 September			
From 11:00: Registration of participants			
13:30: Opening Session			
13:30	Opening of the Workshop, DAbG Welcome Address	Dirk Schulze-Makuch	Bord of the DAbG
13:45	GFZ Welcome Address	Dirk Wagner	GFZ, Section Geomicrobiology
Session 1: Origin of Life			
Chair: *Jean-Pierre de Vera*			
14:00	Kuhan Chandru	A Contingency-Based Non-Biocentric Model of Astrobiology	
14:20	Mickael Baqué	Field expedition to the Kerguelen islands: geothermal hot springs as a window on the origin of life and analogs for extraterrestrial environments	
14:40	Christian Mayer	Spontaneous structural development of a peptide-vesicle system towards possible protocells	
15:00	**Coffee Break**		
Keynote Lecture 1			
Chair: *Christian Mayer*			
15:30	Frank Postberg	Exploring the habitability of ocean moons by mass spectrometry of emitted ice grains	
Session 2: Exoplanets			
Chair: *Lena Noack*			
16:00	Alexander Thamm	Modeling the composition of planetary building blocks in the protoplanetary disk of TRAPPIST-1	
16:20	Iva Volovic	Probing Superhabitable Worlds: Modeling Exoplanetary Atmospheres for simulated JWST Observations	

Session 3: Space Exploration 1		
Chair: *Frank Postberg*		
16:40	Nozair Khawaya	Detecting Biosignatures across the Solar System using Spaceborne Mass Spectrometers
17:00	Jean-Pierre de Vera	Life Detection and Habitability Studies on the ISS as Precursor Mission to the Astrobiological Exploration of Mars and the Icy Ocean Worlds
Tuesday 17 September		
Keynote Lecture 2		
Chair: *Dirk Schulze-Makuch*		
9:15	Jorge Vago	Searching for Signs of Life on Mars with Rosalind Franklin
Session 4: Space Exploration 2		
Chair: *Maryse Napoleoni*		
10:15	Fabian Klenner	Astrobiology Research on Icy Moons and Ocean Worlds – Contributions from Germany
10:35	Maryse Napoleoni	Detecting Fe (II) and Fe (III) in Ice Grains with Mass Spectrometry: Implications for the Geochemistry and Habitability of Europa and Enceladus
10:55	Dirk Schulze-Makuch	We May Have Overlooked the Presence of Life on Mars
11:15	**Coffee break**	
Session 5: Planetary Microbiology 1		
Chair: *Dirk Wagner*		
11:45	Timo Babel	Bacteria in space- Investigation of cyanobacteria for moon habitats and their relevance for future missions
12:05	Berke Duarte dos Santos	Assessing the Impact of Microbial Separation Techniques on Motility and Viability in Martian Sediments
12:25	Florian-Carlo Fischer	Microbial Survival in simulated Mars-like subsurface conditions: The impact of Mars-relvant salts
12:45	Jacob Heinz	Microbial Adaptation to Martian Salts
13:05	**Lunch break**	
13:50	Guided tour Telegrafenberg campus (meeting point in front of canteen at “Column Forum”)	
15:30	**Coffee break**	
16:00	Mitgliederversammlung	

19:00	**Dinner at El Puerto**	
	Wednesday 18 September	
Session 6: Planetary Microbiology 2		
Chair: *Janosch Schirmack*		
09:15	Tom Janetzek	Monitoring and prediction of microbial diversity and its interaction with the environment by artificial intelligence - large scale monitoring and prediction of microbial biodiversity in the soil on Earth and beyond
09:35	Shivani Nundo	Potential Martian habitats: Halotolerant organisms in deliquescence-driven brines
09:55	Dirk Wagner	Persistent and surface independent microbial communities inhabiting deep soils of the hyperarid Atacama Desert
10:15	Coffee Break	
Session 7: Biosignatures		
Chair: *Mickaël Baqué*		
10:45	Felix Arens	Mars analog long-term exposure experiments to quantify the degradations of biomarkers in the Atacama Desert
11:05	Hans Brückner	Microbial Polypeptides (Peptaibiotics) in the Cloud Layer of Planet Venus?
11:25	Marie Dannemann	Biosignatures of a putative inhabitant of Enceladus' ocean surface
11:45	**Award Ceremony and Final Remarks**	
12:05	Tour de GeoBioLab	
13:15	**Lunch**	

Oral Contributions

Keynote Lecture 1

Exploring the habitability of ocean moons by in situ analysis of emitted ice grains

Frank Postberg

Institut für Geologische Wissenschaften, Freie Universität Berlin

Saturn’s icy moon Enceladus harbours a global ocean, which lies under an ice crust but has a rocky sea floor. Through warm cracks in the crust a cryo-volcanic plume ejects ice grains and vapour into space providing access to materials originating from the ocean. Hydrothermal activity is suspected to be occurring deep inside the water-percolated porous rocky core and powered by tidal dissipation. Two mass spectrometers aboard the Cassini spacecraft, frequently carried out compositional in situ measurements of vapor and ice grains emerging from the subsurface of Enceladus.

In the first part of the presentation, we summarize the current knowledge about the habitability of Enceladus’ ocean - including the latest finding of abundant phosphate dissolved in it. In the second part we look forward to the future exploration of ocean worlds by space missions using mass spectrometry. In particular NASA’s Europa Clipper Mission scheduled for launch in October 2024 and ESA’s future flagship mission (L4) with the main goal to search for extant life on Enceladus.

Keynote Lecture 2

Finding signs of life elsewhere is one of the most important scientific objectives of our time.

J. L. Vago and E. Sefton-Nash and the ExoMars Science Working Team (ESWT)

European Space Agency, ESTEC, the Netherlands (jorge.vago@esa.int)

From the very beginning in 2002, ExoMars was conceived to answer one question: Was there ever life on Mars? All project design decisions have focused and continue to centre on the achievement of this one scientific goal. This is particularly the case for the Rosalind Franklin rover. Putting the science team in the best possible condition to search for physical and chemical biosignatures has led to:

1. The need to have a 2-m depth drill;
2. The choice of payload instruments (including the trade-offs we had to make).
3. The requirements for the science potential and age of the landing site.
4. The surface exploration strategy: which targets, how much travelling, and the way that the instruments will be used together.

This presentation will explain how this came about and what ESA is doing to reconfigure the Rosalind Franklin mission for a launch in 2028.

As an advance:

A new European Entry Descent and Landing Module (EDLM) will deliver Rosalind Franklin to Oxia Planum, following a long trajectory to ensure that the rover touches down at the beginning of spring.

The revised mission is being prepared in partnership with NASA, who will contribute the launcher, the descent engines for the lander, and radioisotope heating units (RHUs) for the rover.

The electronic boards of the rover analytical laboratory instruments are being refurbished. A new mast infrared spectrometer ‘Enfys’ is in development to replace the disembarked ISEM instrument.

Session 1: Origin of Life

A Contingency-Based Non-Biocentric Model of Astrobiology

Chandru, K

Universität Duisburg-Essen, Physikalische Chemie, Essen, Germany

Astrobiology involves deciphering the origins of life using prebiotic chemistry and leveraging this knowledge to search for life beyond Earth. To date, most studies have been heavily biocentric, focusing on biomolecules as the essential building blocks of life, both terrestrial and extraterrestrial. However, this approach has not yet yielded definitive results, highlighting the need for more innovative methods. Therefore, we propose a non-biocentric model viewed through the lens of contingency.

In this work, we incorporate contingency with alternative prebiotic molecules (while still using carbon compounds) and diverse environmental conditions that might give rise to life on and off Earth. Our aim is to expand the search for extraterrestrial life beyond traditional biocentric paradigms.

Field expedition to the Kerguelen islands: geothermal hot springs as a window on the origin of life and analogs for extraterrestrial environments

Baqué M.[1], Le Moigne M.[2], Guillaume D.[3], Le Romancer M.[4], Foucher F.[5], and Alain K.[2]

[1]German Aerospace Center (DLR), Institute of Planetary Research, Planetary Laboratories Department, Berlin, Germany; [2]Univ Brest, CNRS, Ifremer, EMR 6002 Biology, interactions and adaptations of organisms in extreme environments, Plouzané, France; [3]Université Jean Monnet Saint-Etienne, CNRS, LGL-TPE UMR5276, Saint-Etienne, France ; [4]UBO, UFR Sciences et Techniques, UR 7462, Laboratoire Géoarchitecture, Territoires, Urbanisation, Biodiversité, Environnement, Brest, France; [5]CNRS-Conditions Extrêmes et Matériaux: Haute Température et Irradiation, Orléans, France.

The geothermal habitats of the French Southern and Antarctic Lands (more than 40 terrestrial and submarine sources) are unique biodiversity sanctuaries in very remote polar environments with contrasting harsh physico-chemical conditions. The microbial communities they host have been the subject of only a few studies and remain largely unknown. The aim of the IPEV project SEKMET (Sub-Antarctic hot Environments of Kerguelen and Saint-Paul: Microbial diversity and Extra Terrestrial analogues), led by the CNRS-IFREMER-UBO, (bringing together 14 different partners) is to carry out a first global inventory of bacterial, archaeal, viral, microeukaryotic and fungal communities of the geothermal habitats of the Kerguelen and St. Paul islands with new omics tools (metagenomics, metatranscriptomics…) but also cultivation methods to isolate interesting new species and taxa. The astrobiology focus is on the thermal mineral springs with silica or carbonate deposits as they represent a key to understanding the primitive life forms on Early Earth and potentially Early Mars. A first sampling campaign took place in 2023-2024 and samples and data are currently being processed. *In situ* and laboratory Raman analyses will tentatively shed some light on the preservation of microorganisms and of their associated biosignatures in these unique environments.

Spontaneous structural development of a peptide-vesicle system towards possible protocells

Christian Mayer[1], Ulrich Schreiber[2], María J. Dávila[1], Oliver J. Schmitz[3], Yildiz Großmann[3]

[1]Institute of Physical Chemistry, CENIDE, University of Duisburg-Essen, 45141 Essen, Germany; [2]Department of Geology, University of Duisburg-Essen, 45141 Essen, Germany; [3]Institute of Applied Analytical Chemistry, University of Duisburg-Essen, 45141 Essen, Germany.

Life is characterized by significant complexity combined with a high degree of order. Therefore, early steps towards the origin of life must have necessarily led into this direction. The most powerful process leading to states of increased complexity and order is Darwinian evolution. However, this requires self-reproducing systems. So which processes, instead of Darwinian evolution, could have developed complex prebiotic structures in the early beginnings?

First, a necessary precondition for development is a permanent non-equilibrium state. This is most easily achieved by a constant variation of physical conditions, such as switching between states of wetness and dryness, or by fluctuating temperature or pressure conditions. This combined with the formation and selection of complex molecular structures has the power to lead from simple chaotic mixtures toward larger, more defined entities. Perfect conditions for such a development are found in the Earth's crust.

Recent experiments in our lab rely on pressure cycling, simulating the conditions in the Earth's crust in a depth of 1 km. We can show that, in presence of simple prebiotic molecules, these conditions lead to the periodic formation of vesicles. These vesicles in turn select peptides generated randomly in a pool of amino acids. The resulting vesicle-peptide structures are constantly selected for their stability, leading to an ongoing optimization process. In total, a process is formed which leads to continuous increase in order (selected peptide sequences) and complexity (growing size of the peptides).

Fig. 1 shows the experimental result of such an autonomous selection process, a functional peptide structure formed inside a membrane of the "surviving" vesicles. It has the capability to stabilize the vesicle, alter its size and allow for an increased water permeability in order to reduce osmotic pressure load.

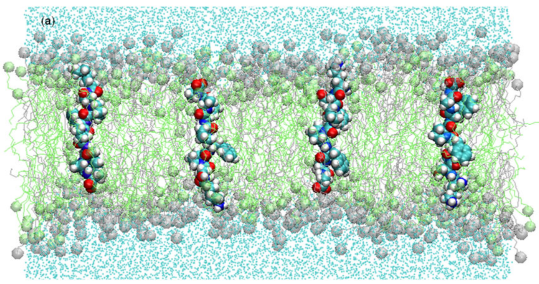


Fig. 1:
Initial stage of a membrane structure formed from small molecules by a spontaneous structural development during pressure cycling. In a subsequent step, the integrated peptide molecules form hexamers that act as pores in the membrane.

References

Mayer, C., Schreiber, U., Dávila M. (2015) Periodic vesicle formation in tectonic fault zones – an ideal scenario for molecular evolution, *Origins of Life and Evolution of Biospheres* 45: 139-148.

Mayer, C., Schreiber, U., Dávila, M. (2017) Selection of prebiotic molecules in amphiphilic environments, *Life* 7: 3.

Mayer, C., Schreiber, U., Dávila, M., Schmitz, O.J. et al. (2018) Molecular evolution in a peptide-vesicle system, *Life* 8: 16.

Mayer, C. (2020) Life in the context of order and complexity, *Life* 10, 5.

Davila, M., Mayer C. (2022) Membrane structure obtained in an experimental evolution process, *Life* 12: 145.

Davila, M., Mayer C. (2023) Structural phenomena in a vesicle membrane obtained through an evolution experiment, *Life* 13: 1735.

Session 2: Exoplanets

The influence of mantle oxygen fugacity and outgassing efficiency on the composition of secondary atmospheres on exoplanets

Brachmann, C[1,2]; Noack, L[2]; Baumeister, P[2]; Sohl, F[1]

[1]German Aerospace Center, Rutherfordstr. 2, 12489 Berlin; [2]Freie Universität Berlin, Malteserstr. 74 -100, 12249 Berlin.

Rocky exoplanets' internal constitution is inferred from their atmospheric composition, requiring coupled interior and atmospheric models. Traditional atmospheric models focused on element abundance, temperature, and pressure but ignored volcanic degassing's role in forming present-day atmospheres. We integrated volcanic outgassing with an atmospheric chemistry model to simulate C-H-O-N-S atmospheres below 600 K. These volatiles, commonly stored in basaltic magmas, are critical for atmospheric composition.

Our model assesses atmospheric compositions by varying oxygen fugacity, melt and surface temperatures, and volatile abundances, considering factors like phase solubility, water condensation, and hydrogen escape. We found that below 600 K, atmospheres typically contain CO_2, N_2, CH_4, and sometimes H_2O, influenced significantly by the melt's oxygen fugacity. Reduced conditions lead to H_2, NH_3, CH_4, and H_2O with low pressures, while oxidized conditions result in H_2O, CO_2, N_2, and limited CH_4 with high pressures. Sulfur gases vary with surface temperature and mantle redox states, appearing as S_2 or H_2S in low redox and SO_2 in high redox conditions. O_2 is not abiotically generated due to available carbon or hydrogen.

In addition, we demonstrate that reduced magmas can oxidize via H_2 and CO degassing, whereas oxidized magmas may undergo reduction through SO_2 degassing. Furthermore, we conclude atmospheric composition is influenced by magma source depth and planetary size due to pressure-dependent solubility of degassed species.

Modeling the composition of planetary building blocks in the protoplanetary disk of TRAPPIST-1

Thamm, A, Noack, L and Balduin, A

Freie Universität Berlin, Planetary Geodynamics, Berlin

Since stars and their planetary accretion disks are formed by the collapse of the same interstellar dust cloud, the composition of a star can be used as a first estimate of the upper limit of the composition of the accretion disk. We present a model that predicts the composition of planetary building blocks based on the metallicity of the host star. Unlike complex models such as GGChem or FastChem, the presented model prioritizes speed and simplicity, providing a fast, accessible first-order approximation for easy integration into more complex models.

Using this model, we estimate the composition of the TRAPPIST-1 planets, demonstrating its practical application. We obtain three different compositional clusters, including dominantly dry (TRAPPIST-1 b-c) water rich (TRAPPIST-1 e,f) and water- and ammonium-rich building blocks. Furthermore, using an interior structure model (Noack et al. 2016), we predict the core mass fraction and radii for the inner planets, which agree well with the observed values from Agol et al. (2021), and suggest that the outer planets should have a maximum water fraction below 20 wt% to match their observed radii. These results validate the ability of our model to accurately predict planetary composition to a first approximation and indicate minimal compositional change during accretion.

Probing Superhabitable Worlds: Modeling Exoplanetary Atmospheres for simulated JWST Observations

Iva Vilović[1*], Jayesh Goyal[2], and René Heller[3]

[1]Astrobiology Research Group, Zentrum für Astronomie und Astrophysik, Technische Universität Berlin, 10623 Berlin, Germany; [2]School of Earth & Planetary Sciences (SEPS), National Institute of Science Education & Research (NISER), Bhubaneshwar, Odisha - 752050, India; [3]Max-Planck-Institut für Sonnensystemforschung, 37077 Göttingen, Germany.

In our search for life in the Universe, there may be planetary bodies that are more habitable for life than Earth. Even Earth's habitability varied enormously throughout the eons. We call worlds that are more habitable than Earth today ‘superhabitable’. K dwarf stars, characterized by stable luminosity evolutions, stand out as promising hosts for such superhabitable realms. These stars also offer extended stability within the habitable zone, crucial for the emergence and sustenance of life. Planets orbiting K dwarfs, with up to twice Earth’s mass and around 25% larger than Earth, could potentially qualify as superhabitable. This configuration allows for a denser atmosphere, facilitating an expanded biosphere and enhancing detectability through remote observations.

Our recent study investigated the effects of simulated K-dwarf radiation on garden cress and cyanobacteria, revealing their capability to grow under this modified radiation environment. Building upon these findings, here we use theoretical models to evaluate the detectability of superhabitable conditions using the James Webb Space Telescope (JWST). Combining the *Atmos* climate-photochemistry model with the *POSEIDON* forward model and the *PandExo* tool for simulating JWST observations, our preliminary results indicate that superhabitable environments significantly positively influence the observability of key spectral features, such as oxygen, carbon dioxide and ozone. Furthermore, these spectral features require much fewer transits for detection with the JWST compared to a modern Earth counterpart. These findings underscore the importance of focusing on exoplanets orbiting K dwarf stars within their habitable zones, utilizing state-of-the-art instrumentation, in our search for life beyond the Solar System.

Session 3 and 4: Space Exploration

Simulating mass spectral fingerprints of macromolecular organics in Enceladus ice grains

H Sánchez, Lucía[1]; Napoleoni, Maryse[1]; Ackley, Mirandah[1]; Klenner, Fabian[2]; Khawaja, Nozair[3]; Postberg, Frank[1]

[1]Institute of Geological Sciences, Freie Universität Berlin, Germany; [2]Department of Earth and Space Sciences, University of Washington, Seattle, USA; [3]Institute of Space Systems, University of Stuttgart, Germany

Saturn's moon Enceladus emits into space a plume of gas and ice grains formed from a subsurface water ocean [1,2]. The Cosmic Dust Analyzer (CDA), one of the mass spectrometers on board the Cassini spacecraft [3,4], analysed the compositions of the emitted ice grains. Some of these ice grains contain complex macromolecular organic compounds [5] (above 200 u), suggested to originate from a thin organic-rich film on top of the oceanic water table. The structure of these macromolecular organic compounds has been previously partially constrained: CDA's cation mass spectra show a sequence of repetitive peaks beyond 80 u, usually separated by intervals of 12 or 13 u, suggesting unsaturated carbon atoms to be part of the molecule's structure. Thus, they can be referred to as high-mass organic cations (HMOC) [6].

Ongoing laboratory analogue experiments are carried out to find a suitable spectral match for the HMOC fingerprint. Several samples, each containing one of a diverse range of plausible organic compounds, were measured using the Laser Induced Liquid Beam Ion Desorption (LILBID) technique [7], which reproduces the impact ionization mass spectra of ice grains as produced by CDA-type instruments [8]. Preliminary results constrain the possible types of HMOC composition.

References:

[1] Porco, C. C. et al. Cassini observes the active south pole of Enceladus. *Science* **311**, 1393–1401 (2006).
[2] Postberg, F. et al. Sodium salts in E ring ice grains from an ocean below the surface of Enceladus. *Nature* **459**, 1098–1101 (2009).
[3] Srama, R., Ahrens, T.J., Altobelli, N. et al. The Cassini Cosmic Dust Analyzer. Space Sci Rev **114**, 465–518 (2004)
[4] Waite, J. H. et al. Cassini Ion and Neutral Mass Spectrometer: Enceladus plume composition and structure. *Science* **311**, 1419–1422 (2006).
[3] Hsu, HW. et al. Ongoing hydrothermal activities within Enceladus. *Nature* **519**, 207–210 (2015).
[5] Khawaja, N. et al. Low-mass nitrogen-, oxygen-bearing, and aromatic compounds in Enceladean ice grains. *Monthly Notices of the Royal Astronomical Society* **489**, 4, 5231–5243 (2019).
[6] Postberg, F. et al. Macromolecular organic compounds from the depths of Enceladus. *Nature* **558**, 564–568 (2018).
[7] Klenner, F. et al. Analogue spectra for impact ionization mass spectra of water ice grains obtained at different impact speeds in space. *Rapid Commun Mass Spectrom* **33**, 1751– 1760 (2019).
[8] Napoleoni, M. et al. Mass Spectrometric Fingerprints of Organic Compounds in Sulfate-Rich Ice Grains: Implications for Europa Clipper. *ACS Earth Space Chem* **7**, 9, 1675–1693 (2023).

Detecting Biosignatures across the Solar System using Spaceborne Mass Spectrometers

Nozair Khawaja[1,2], Ralf Srama[1], Jonas Simolka[1], Frank Postberg[2], Yanwei Li[1], Anna Mocker[1], Heiko Strack[1]

[1]Institute of Space Systems, University of Stuttgart, Germany; [2]Institute of Geological Sciences, Freie University Berlin, Germany

Cosmic dust is a phenomenon that can be observed across the solar system and beyond. Such as the dust cloud lofted from the surface of Earth's moon to the further reaches of the outer solar system, e.g. Saturn's rings, and even beyond in the interstellar space. The size distribution of these tiny particles ranges from nanometre up to millimetre scales [1,2]. These particles consist of silicates and carbonaceous material that could also contain biosignatures [3]. The spaceborne dust detectors intercept these micron and sub-micron sized particles in space at high velocities, fragmenting them and ionising their components, yielding information on the composition of these grains. Here, we present the work done by Cassini's Cosmic Dust Analyzer (CDA) on the detection of organic compounds with astrobiological potential from local Saturn-bound dust, at Saturn [4,5]. Similar spaceborne mass spectrometers (Destiny+ Dust Detector (DDA) and SUrface Dust Analyzer (SUDA)) will be among payload of future space missions. These detectors are planned to fly with JAXA's Destiny+ space mission to investigate the composition of emitted dust grains from the asteroid Phaethon [6] and also with NASA's Europa-Clipper mission to sample and analyse ejected icy dust particles from the surface of Jupiter's moon Europa [7].

References:

[1] Khawaja N. et al. (2024), Exploring the universe through dust visions. Phil. Trans. R. Soc. A. 382:20230210. https://doi.org/10.1098/rsta.2023.0210.
[2] Grun E., Kruger, H. & Srama, R. (2019), The Dawn of Dust Astronomy. Space Sci Rev 215, 46 (2019). https://doi.org/10.1007/s11214-019-0610-1.
[3] Totani T. (2023), Solid grains ejected from terrestrial exoplanets as a probe of the abudnace of life in the Milky Way. Inter. Jour. Of Astrobio. 22 (4): 347-353, doi:10.1017/S147355042300006X.
[4] Khawaja N. et al. (2019), Low-mass nitrogen-, oxygen bearing, and aromaGc compounds in Enceladean ice grains. MNRAS 489, pp. 5231– 5243. https://doi.org/10.1093/mnras/stz2280.
[5] Postberg F. & Khawaja N. et al. (2018), Macromolecular organic compounds from the depths of Enceladus. Nature 558 (7711), pp. 564- 568. https://doi.org/10.1038/s41586-018-0246-4.
[6] Simolka J. et al. (2024), The DESTINY+ Dust Analyser — a dust telescope for analysing cosmic dust dynamics and composition. Phil. Trans. R. Soc. A. 382:20230199. https://doi.org/10.1098/rsta.2023.0199.
[7] Kempf S. et al. (2014), SUDA: A Dust Mass Spectrometer for Compositional Surface Mapping for a Mission to Europa. EPSC Vol. 9, EPSC2014-229.

Life Detection and Habitability Studies on the ISS as Precursor Mission to the Astrobiological Exploration of Mars and the Icy Ocean Worlds

de Vera, J-P-P[1], Baqué, M.[2] and BioSigN team[3]

[1]German Aerospace Center (DLR), Space Operations and Astronaut Training, MUSC, Cologne, Germany; [2]German Aerospace Center (DLR), Institute of Planetary Research, Planetary Laboratories, Berlin, Germany; [3]BioSigN team: Ute Böttger, Jörn Helbert, Frank Sohl, Andreas Lorek, Andreas Elsaesser, Dirk Wagner, Thomas Berger, Ralf Möller, Peter Lasch, Peter Heisig, Anke Heisig, Daniela Billi, Silvano Onofri, Laura Selbmann, Laura Zucconi, Barbara Cavalazzi, Frances Westall, Frédéric Foucher, Rosa de la Torre, Jesús M. Frías, Karen Olsson-Francis, Deb Barh, Charles S. Cockell, Markus Braun, Elke Rabbow, Dirk Schulze-Makuch, Marina Walther-Antonio, Ilka Axmann, Bernard Foing, Rodrigo Coutinho de Almeida, Natalia Kozyrovska, Agata Kołodziejczyk, John Brucato, Autun Purser, Alessandro Maturilli, Solmaz Adeli, Jan Bredehöft, Cyprien Verseux, Christoph Waldmann, Frank Postberg, Nozair Khawaja, Alessia Cassaro, Henry Strasdeit, Claudia Pacelli, Tadeusz Uhl, Michelle Gehringer, Fabian Klenner, Aristóteles Góes Neto, Vasco Azevedo

BioSigN (**BioSig**natues and habitable **N**iches) is a space experiment supported by ESA and foreseen to be performed in Low Earth Orbit on the exposure facility Exobio on the external experiment platform Bartholoméo what will be fixed outside the Columbus Module on the International Space Station (ISS). Comparable to the previous space experiment BIOMEX [1,2] but further improved, the main objective of BioSigN is to support and prepare future planetary exploration missions to Mars, Enceladus, Europa and/or Titan by conducting exposure experiments on the ISS. To maximize the scientific output, the outcome of BioSigN will be connected to the results obtained on ground from recent and up-coming planetary analogue field site studies and planetary simulation facilities. The BioSigN project is conceived to achieve three central objectives:

- To analyze to what extent selected organisms and (micro-)fossils acquired from Icy Moon/Mars analogue field sites (terrestrial and ocean/deep sea location) can survive/outlast the conditions of space exposure;
- To evaluate by the obtained results the habitability of present/past Mars and of the icy ocean worlds in the solar system.
- To test the (in)stability of a particular set of bio-molecules when exposed to space and Mars-like conditions, and to investigate their mechanisms of resistance or degradation as well as analyzing if they are still detectable by the commonly used life detection methods;

To reach these goals, the test samples will be exposed to space vacuum and space radiation, approaching icy-moon specific or planet-specific atmospheric and solar environments. In this presentation there will be a particular focus on presenting the selected samples, the planned simulation experiments on ground and in space as well as the chosen detection methods.

Astrobiology Research on Icy Moons and Ocean Worlds – Contributions from Germany

Klenner, F[1], Baqué, M[2], Beblo-Vranesevic, K[3], Bönigk, J[4], Boxberg, MS[5], Dachwald, B[6], Digel I[7], Elsaesser A[8], Espe, C[9], Funke, O[10], Hauber, E[11], Heinen, D[12], Hofmann, F[8], Hortal Sánchez, L[4], Khawaja, N[4,13], Napoleoni, M[4], Plesa, A-C[11], Postberg, F[4], Purser, A[14], Rückriemen-Bez, T[11], Schröder, S[15], Schulze-Makuch, D[16,17,18,19], Ulamec, S[20] and de Vera, J-P[20]

[1]Department of Earth and Space Sciences, University of Washington, Seattle, USA; [2]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany; [3]Institute of Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany; [4]Institute of Geological Sciences, Freie Universität Berlin, Berlin, Germany; [5]Geophysical Imaging and Monitoring, RWTH Aachen University, Aachen, Germany; [6]Faculty of Aerospace Engineering, FH Aachen University of Applied Sciences, Aachen, Germany; [7]Institut für Bioengineering, FH Aachen University of Applied Sciences, Jülich, Germany; [8]Experimental Space Science and Biophysics, Freie Universität Berlin, Berlin, Germany; [9]GSI - Gesellschaft für Systementwicklung & Instrumentierung mbH, Aachen, Germany; [10]German Space Agency at DLR, German Aerospace Center (DLR), Bonn, Germany; [11]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany; [12]Physics Institute III B, RWTH Aachen University, Aachen, Germany; [13]Institute of Space Systems, University of Stuttgart, Germany; [14]Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany; [15]Institute of Optical Sensor Systems, German Aerospace Center (DLR), Berlin, Germany; [16]Astrobiology Group, Center of Astronomy and Astrophysics, Technische Universität Berlin, Berlin, Germany; [17]Section Geomicrobiology, GFZ German Research Center for Geosciences, Potsdam, Germany.; [18]Department of Experimental Limnology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Stechlin, Germany; [19]School of the Environment, Washington State University, Pullman, USA; [20]Microgravity User Support Center (MUSC), German Aerospace Center (DLR), Cologne, Germany

Icy moons and ocean worlds are prime targets for astrobiology investigations. An increasing number of scientists contribute to the development and realization of space missions to these worlds. The Ocean Worlds and Icy Moons working group of the German Astrobiology Society provides an invaluable platform within Germany to share knowledge and start collaborations. We here present an overview about astrobiology research related to icy moons and ocean worlds conducted in Germany or in strong collaboration with scientists or engineers in Germany (Klenner et al., 2024). This includes the strategic view of the German government, published recently in its space program strategy document (BMWK, 2023) as well as currently ongoing projects involving experimental studies, numerical simulations, field work or the development of melting probes. With recent developments, Germany offers itself as a partner to contribute to space missions to icy moons or ocean worlds.

References:

BMWK (2023). Raumfahrtstrategie der Bundesregierung, *Bundesministerium für Wirtschaft und Klimaschutz (BMWK)*, Berlin, pp. 1–60.

Klenner F, et al. (2024). Icy Ocean Worlds - Astrobiology Research in Germany. *Front. Astron. Space Sci.*11, in press.

Detecting Fe (II) and Fe (III) in Ice Grains with Mass Spectrometry: Implications for the Geochemistry and Habitability of Europa and Enceladus

Maryse Napoleoni[1], Lucía Hortal Sánchez[1], Nozair Khawaja[1,2], Bernd Abel[3,4], Christopher Glein[5], Jon K. Hillier[1] & Frank Postberg[1]

[1]Institute of Geological Sciences, Freie Universität Berlin, Germany; [2]Institute of Space Systems, University of Stuttgart, Germany; [3]Leipzig Universität, Germany; [4]Leibniz-Institut für Oberflächenmodifizierung (IOM), Leipzig, Germany; [5]Southwest Research Institute, San Antonio, Texas, USA.

The SUrface Dust Analyzer (SUDA) onboard the upcoming Europa Clipper mission can analyze ice grains ejected from Europa and detect ocean-derived salts therein, thus bringing valuable information about the geochemistry and habitability of the subsurface ocean. Transition metals with several oxidation states, such as iron, may be tracers of the oxidation state of the moon's interior. We recorded analogue mass spectra of Fe^{2+} and Fe^{3+} sulfates and chloride using the Laser Induced Liquid Beam Ion Desorption - a technique shown to accurately reproduce SUDA-type mass spectra (Klenner et al. 2019). Our results show that SUDA can detect and differentiate Fe^{2+} from Fe^{3+} ions in both cation and anion modes (Napoleoni et al. 2024). We draw implications for the pH values and oxidation state of the subsurface ocean for difference cases of (non) detection and characterization of iron in ice grains. Such characterization of the geochemistry could be used to further develop different models of redox chemistry in the ocean of Europa but also Enceladus, and have important implications for hydrothermal processes and potential metabolic pathways that may be used by possible extant life in subsurface oceans.

References:

Klenner et al. (2019) *Rapid Commun. Mass Spectrom.*, 33(22), 1751-1760
Napoleoni et al. (2024) *The Planetary Science Journal*, 5(4), 95

We May Have Overlooked the Presence of Life on Mars

Schulze-Makuch, D. [1,2,3]

[1]Astrobiology Group, ZAA, Technische Universität Berlin, Hardenbergstr. 36A, 10623 Berlin, Germany; [2]German Research Centre for Geosciences (GFZ), Section Geomicrobiology, 14473 Potsdam, Germany; [3]Department of Plankton and Microbial Ecology, Leibniz Institute of Freshwater Ecology and Inland Fisheries, 16775 Stechlin, Germany

Email: schulze-makuch@tu-berlin.de

One of humanity´s most ancient questions is whether life exists elsewhere in the Universe. While the search for unambiguous evidence for life beyond Earth is ongoing, we may have overlooked its previous detection in the only life detection experiment ever conducted on another planet: the Viking lander experiments on Mars in the 1970s. New insights from recent Mars missions, such as Curiosity and Perseverance, along with a better understanding of the hyperarid Martian environment and how life might adapt to it, lead to the conclusion that Viking might have in fact detect living organisms, only to accidently kill them. While the Martian environment is extremely challenging for life, organisms may still survive and thrive by attracting water from the relative humidity of the Martian atmosphere using the hygroscopicity of salts such as sodium chloride or (per)chlorates. If these inferences are correct, we should “follow the salt” rather than only the water and search for active life on Mars in hygroscopic salt regions such as the Southern Highlands.

Session 5 and 6: Planetary Microbiology

Bacteria in space- Investigation of cyanobacteria for moon habitats and their relevance for future missions

Babel T[1], Axmann IM[1]

Heinrich-Heine-University, Duesseldorf

Cyanobacteria are ubiquitous in the world. Cyanobacteria are the only prokaryotes capable of photosynthesis and are considered a pre-evolutionary stage of today's chloroplasts [1]. In recent developments the interest in prokaryotes has increased with regards to space travel since they can be a reliable producer of materials with only minimal resources [2]. Through rising interest of space travel, it was especially interesting to investigate whether cyanobacteria can survive on the moon surface. For this purpose, cultures were taken from different terrestrial surfaces or aquatic habitats and selected for cyanobacteria with antibiotics. Selected cultures were incubated on the lunar rock simulant EAC-1A. Under the conditions used in this study, cyanobacteria grow on the simulant. Especially the strain *Nostoc PCC 7120* (henceforth called *Nostoc*) grew in medium without nitrogen as well as in medium without nitrogen and iron. These results indicate a benefit of the regolith of *Nostoc*. Incubation with the regolith also altered the so-called heterocysts. These showed increased chlorophyll at different time points. First results indicate an involvement of iron in these changes. Goals of further experiments are investigations if those cells are capable of photosynthesis and nitrogen fixation at the same time. As new members of the BioSigN project we are looking forward to test this behaviour further under nearly real conditions.

References:

[2] Sagan, L. (1967). "On the origin of mitosing cells." Journal of Theoretical Biology 14(3): 225-IN226.
[3] Golombek, M. P., R. A. Cook, T. Economou, W. M. Folkner, A. F. C. Haldemann, P. H. Kallemeyn, J. M. Knudsen, R. M. Manning, H. J. Moore, T. J. Parker, R. Rieder, J. T. Schofield, P. H. Smith and R. M. Vaughan (1997). "Overview of the Mars Pathfinder Mission and Assessment of Landing Site Predictions." Science 278(5344): 1743-1748.

Assessing the Impact of Microbial Separation Techniques on Motility and Viability in Martian Sediments

Max Riekeles[1], Berke Santos[2], Dirk Schulze-Makuch[1,3,4]

[1]Astrobiology Group, Center of Astronomy and Astrophysics, Technical University Berlin, Germany; [2]Instituto Superior Técnico, Lisbon, Portugal; [3]German Research Centre for Geosciences (GFZ), Section Geomicrobiology Potsdam, Germany; [4]Department of Plankton and Microbial Ecology, Leibniz Institute of Freshwater Ecology and Inland Fisheries, Stechlin, Germany;

Microscopy offers a promising approach for detecting potential extraterrestrial microbiological life on Mars. However, separating microbes from Martian regolith, which may contain minerals or compounds interfering with detection, is a critical challenge. Additionally, treating the regolith may expose these microbial lifeforms to chemical and physical hazards. Thus, effective separation methods are crucial in the search for extraterrestrial life.

We tested various physical separation methods using *Escherichia coli* and Martian Analog regolith samples, specifically Mojave Mars Simulant 2 (MMS-2). The separation techniques included ultrasonication, vortex shaking, hand shaking, and filtration. Each technique was evaluated independently and over different time intervals to assess their impact on the concentration, viability, and motility of the extracted microbes.

Ultrasonication used a sonication bath, vortex shaking utilized a standard laboratory vortex mixer, and hand shaking involved repeated inversions. Filtration was conducted using 0.2 μm syringe filters.

Our results emphasize the importance of separation methods that minimize cell damage, preserving the integrity of potential microbial life. By evaluating the performance of each technique, we assessed their overall extraction efficiency and effectiveness. Therefore, our research highlights the need for reliable techniques in future astrobiological investigations to ensure the precise identification of potential Martian life.

Microbial Survival in simulated Mars-like subsurface conditions: The impact of Mars-relvant salts.

Fischer, Florian Carlo[1]; Schulze-Makuch, Dirk[1,2,3]; Heinz, Jacob[1]

[1] Center for Astronomy and Astrophysics, RG Astrobiology, Technische Universität Berlin, Berlin, Germany; [2] GFZ German Research Center for Geosciences, Section Geomicrobiology, Potsdam, Germany; [3] Department of Plankton and Microbial Ecology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Stechlin, Germany.

The Martian surface and shallow subsurface lack stable liquid water, but hygroscopic salts in the regolith may allow transient liquid brine formation. This study examined the effects of water scarcity, UV exposure, and regolith depth on microbial survival under Mars-like conditions. Vegetative cells of *Debaryomyces hansenii* and *Planococcus halocryophilus*, along with spores of *Aspergillus niger*, were exposed to a simulated Martian environment (constant -11 °C, ~6 mbar pressure, CO_2 atmosphere, and 2 hours of daily UV irradiation). We assessed colony-forming units (CFU) and water content at three regolith depths before and after 3 and 7 days of exposure. Each organism was tested under three conditions: salt-free regolith, regolith with sodium chlorate, and regolith with sodium perchlorate. Results showed that residual water content and microbial survival rates increased with regolith depth in chlorate-containing and salt-free samples. In perchlorate-containing regolith, survival rates were consistently lower for all organisms and depths compared to chlorate, with the most significant difference observed at 10-12 cm depth, the depth with the highest residual water content. This is likely due to increased salt concentration from water freezing, indicating that perchlorate brines are more toxic than chlorate brines, highlighting their importance for the habitability of Mars.

Microbial Adaptation to Martian Salts

Heinz, J[1] and the BRINES team[2]

[1]Research Group Astrobiology, Center for Astronomy and Astrophysics, Technische Universität Berlin, Germany.

[2]Including all students (Camilo Mayr-Wolf, Florian Carlo Fischer, Elisa Soler, Anne Gries, Shivani Nundoo, Lea Kloss, Weronika Julia Lukas, Vita Rambags, Ksenia Malahov) involved in the DFG project "BRINES" (#455070607), and the research group leader Dirk Schulze-Makuch.

Understanding potential life on Mars requires knowledge of the planet's habitability, particularly concerning salts such as perchlorates (ClO_4^-), prevalent on Mars but rare on Earth. This research explores how microorganisms adapt to Mars-relevant salts, focusing on their tolerance and stress responses.

Our study assessed the salt tolerance of various halophilic and halotolerant microorganisms, their survival under Mars-like conditions, and their stress responses to these salts. Model organisms and environmental isolates were exposed to different concentrations of sodium perchlorate ($NaClO_4$) and other salts to gauge their tolerance levels. Microscopic, proteomic, and metabolomic methods were used for analysis.

Halotolerant microorganisms showed greater tolerance to $NaClO_4$ compared to obligatory halophiles, indicating more flexible adaptability to unusual salts. The halotolerant yeast *Debaryomyces hansenii* exhibited the highest tolerance, prompting further investigation. Proteomic analysis of *D. hansenii* revealed specific stress responses to perchlorates, such as cell wall remodeling and protein glycosylation. Interestingly, Chlorates (ClO_3^-) were tolerated at much higher concentrations than perchlorates, suggesting chlorate-rich areas on Mars might be more habitable.

Comparisons across organisms revealed species-specific adaptation mechanisms with limited overlap, indicating diverse evolutionary strategies for coping with non-NaCl salts such as perchlorates. These findings underscore the importance of understanding microbial adaptations to Martian conditions for advancing astrobiology.

Monitoring and prediction of microbial diversity and its interaction with the environment by artificial intelligence - large scale monitoring and prediction of microbial biodiversity in the soil on Earth and beyond

Janetzek, T[1], Bartholomäus, A[1] and Wagner, D[1,2]

[1]Helmholtz Centre Potsdam – GFZ German Research Centre for Geosciences, Potsdam, Germany; [2]University of Potsdam, Institute of Geosciences, Potsdam, Germany

Microbial communities in soils are crucial in ecological processes, like soil fertility, plant health, decomposing materials and release minerals. They take effect in carbon- and nitrogen cycles and are of central meaning in the fixation and release of greenhouse gases like carbon dioxide and methane. Thus, microorganisms directly influence soil development and habitability, health and climate and are essential for life on earth.

However, measuring microbial communities require specific equipment, analysis and expert knowledge and is thereby expensive and time-consuming and simply not possible in the case of other planets. The continuous development in remote sensing now enables for measuring many soil parameters on global scale. The goal of our study is to develop an AI model that predicts microbial communities, based on environmental parameters using satellite and weather data, on a global level. The study focuses on large scale monitoring of our soil quality on agricultural land and the prediction of microbial greenhouse gas emission.

This application may also contribute to the search for life on Mars. Several satellites currently orbiting Mars collect environmental and weather data. By analyzing parameters through satellite images, the AI model developed in our project could predict the possible existence of microorganisms on Mars. This would provide a tool for astrobiology, enhancing our ability to detect signs of life on other planets.

Potential Martian habitats: Halotolerant organisms in deliquescence-driven brines

Nundoo, Shivani[1]; Fischer, Florian Carlo[1]; Heinz, Jacob[1]; Schulze-Makuch, Dirk[1,2,3]

[1]Center for Astronomy and Astrophysics, RG Astrobiology, Technische Universität Berlin, Berlin, Germany; [2]GFZ German Research Center for Geosciences, Section Geomicrobiology, Potsdam, Germany; [3]Department of Plankton and Microbial Ecology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Stechlin, Germany.

Mars, at the edge of the traditionally defined habitable zone, is a key target for the search for extraterrestrial life due to its most Earth-like properties compared to all the other planetary bodies in the solar system. Scientists focus on liquid water as a prerequisite for life as it's crucial for biochemical reactions and cellular organization. While Mars' low atmospheric pressure and temperature prevent the stability of pure liquid water, seasonal brines formed by deliquescence of hygroscopic salts occurring on Mars such as chlorates or perchlorates could in principle support extremophilic life in these hypersaline solutions.

This study simulates brine formation on Mars using a methodological set up that includes Martian regolith simulant MGS-1 supplemented with deliquescent salts such as NaCl, NaClO3, and NaClO4, absorbing moisture from the relative humidity of the atmosphere, and cells of the halotolerant yeast *Debaryomyces hansenii*. *D. hansenii* was chosen as a model organism due to its high tolerance to (per)chlorates. Results indicate that *D. hansenii* can survive desiccation and demonstrate growth in a deliquescent environment containing NaClO3 and NaCl, while no survival was observed in NaClO4-containing samples. This finding has broader implications for the potential survival of life on Mars, suggesting that while NaClO4 seems to be more harmful to cells, halotolerant organisms might endure NaClO3- and NaCl-rich deliquescence-driven environments.

Persistent and surface independent microbial communities inhabiting deep soils of the hyperarid Atacama Desert

Horstmann, L.[1,2], Lipus, D.[1], Bartholomäus, A.[1], Arens, F.[3], Airo, A.[4], Ganzert, L.[5], Zamorano, P.[6], Schulze-Makuch[1,3,5], D., Wagner, D.[1,7]

[1]GFZ German Research Centre for Geosciences, Potsdam, Germany; [2]Albrecht-von-Haller-Institute for Plant Sciences, Georg August University Göttingen, Göttingen, Germany; [3]Zentrum für Astronomie und Astrophysik, Technische Universität Berlin, Berlin, Germany; [4]Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany; [5]Department of Plankton and Microbial Ecology, Leibniz Institute of Freshwater Ecology and Inland Fisheries, Stechlin, Germany; [6]Laboratorio de Microorganismos Extremófilos, University of Antofagasta, Antofagasta, Chile; [7]Institute of Geosciences, University of Potsdam, 14476 Potsdam, Germany

The Atacama Desert often serves as an analogue for surface habitats on Mars. Regarding the harsh environmental conditions on the Martian surface (high UV, strong temperature fluctuations) deep subsurface environments appears to be more promising for the search of life. Despite the growing interest in a possible deep biosphere on Mars, there is currently only limited knowledge about microbial life in deep Atacama sediments.

The extraction of intracellular DNA from sediment samples from the Yungay Valley revealed a potentially viable microbial community in the subsurface down to a depth of 4.20 meters. While microbial biomass ceases within the upper meter of the soil profile, a buried microbial community re-emerges in underlying alluvial fan deposits below 2 m depth. This community is probably completely isolated from surface water and nutrient supply. We propose that these subsurface communities are sustained by the high gypsum content of the alluvial fan deposits, which could provide an alternative water source. Additionally, chemolithoautotrophic carbon fixation, possibly facilitated by hydrogenotrophic Actinobacteria taxa, may support these microbial populations.

This discovery is expanding our understanding of desert biodiversity suggesting that subsurface niches are colonized under favorable environmental conditions, representing an analogue for subsurface habitable niches on Mars.

Session 7: Biosignatures

Mars analog long-term exposure experiments to quantify the degradations of biomarkers in the Atacama Desert

Arens, Felix L.[1], Uhl, Jenny[2], Schmitt-Kopplin, Philippe[2], Karger, Cornelia[3], Mangelsdorf, Kai[3], Schulze-Makuch, Dirk[1,4,5]

[1]Technische Universität Berlin, Zentrum für Astronomie und Astrophysik, 10623 Berlin, Germany; [2]Helmholtz Zentrum Munchen, Research Unit Analytical Biogeochemistry, 85764 Neuherberg, Germany; [3]Section Organic Geochemistry, Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Germany; [4]Department of Experimental Limnology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, 16775 Stechlin, Germany; [5]GFZ German Research Centre for Geosciences, Section Geomicrobiology, 14473 Potsdam, Germany

This field experiment aimed to investigate the degradation of selected biomolecules and model organisms under the environmental conditions of the hyperarid Atacama Desert, which serves as a Martian analog. Custom-designed plates were used to expose samples to the desert conditions for 2, 4, and 9 months alongside control samples. Throughout the experiment, environmental conditions were continuously monitored. ATP, chlorophyll, and cyanobacteria were exposed within quartz, gypsum, and Mars regolith simulant substrates with no salt, 1 wt% chloride, and 1 wt% perchlorate. ATP concentrations, measured using a bioluminescence assay, indicated that perchlorates significantly promote ATP preservation under these conditions. Chlorophyll decayed so fast that it was not detected via LC-MS in any samples. However, its degradation products were detected that followed non-enzymatic pathways. These decay products were best preserved in the Martian simulant, which shields most effectively from UV-irradiation, compared to the translucent quartz and gypsum. Breakdown products of cyanobacteria were analyzed using FT-ICR-MS, revealing that the presence of salts plays a critical role in their degradation. Our findings demonstrate that both salt composition and substrate type significantly influence preservation. These insights are crucial for elucidating the origin and stability of potential organic molecules under Mars-like environments.

Microbial Polypeptides (Peptaibiotics) in the Cloud Layer of Planet Venus?

<u>Brückner, H</u>[1] and Degenkolb, T[2]

[1]Interdisciplinary Research Centre for BioSystems, Land Use and Nutrition, Department of Food Sciences, Justus-Liebig-University of Giessen, Germany; [2]Department of Insect Biotechnology, Justus-Liebig-University of Giessen, Germany

In a hypotheses article, Kotsyurbenko et al. (2024) discussed different scenarios for the possible occurrence of microbial life in the cloud layers of Venus. As an evolutionary adaption to the assumed composition of the Venusian atmosphere, the authors consider the occurrence of filamentous fungi (ascomycetes) that are able to biosynthesize a group of membrane-modifying polypeptide antibiotics for which the names peptaibols/peptaibiotics became established; see Eichberg et al. (2024) and references cited therein. This unique group of metabolites is characterized by the presence of the eponymous non-proteinogenic amino acid **Aib** (α-aminoisobutyric acid (Brückner et al., 2009). The non-ribosomal biosynthesis of this group of metabolites requires a set of multienzyme complexes, which is currently regarded as typical for the kingdom of fungi. As a hitherto single exception, the synthesis of peptaibols, named microbacterins, from the extremophilic deep-sea actinobacterium *Microbacterium sediminis* has been reported (Liu et al. 2015) but needs to be confirmed.

References:

Kotsyurbenko, O.R. et al. (2024) Different Scenarios for the Origin and the Subsequent Succession of a Hypothetical Microbial Community in the Cloud Layer of Venus. *Astrobiology* 24(4): 423-441. https://doi.10.1089/ast.2022.0117

Eichberg J. et al. (2024) Structural characterization and bioactive profiling of the fungal peptaibiotics tolypin revealed protective effects against influenza viruses. *Arch. Pharm.* E2400384. https//doi.org/10.1002/ardp.202400384

Brückner H., Becker, D., Gams W., Degenkolb T. (2009) Aib and Iva in the Biosphere, neither rare nor necessarily extraterrestrial. *Chemistry and Biodiversity* 6: 38-56. https://doi.org/10.1002/cbdv.200800331

Liu, D. et al. (2015) Microbacterins A and B, New Peptaibols from the Deep Sea Actinomycete *Microbacterium sediminis* sp. nov. YLB-01(T). *Organic Letters* 17: 1220- https://doi.10.1021/acs.orglett.5b00172

Biosignatures of a putative inhabitant of Enceladus' ocean surface

Dannenmann, M[1], Ackley, M[1], Burr, D[2], Postberg, F[1]

[1]Planetary Sciences and Remote Sensing, Institute of Geological Sciences, Freie Universität Berlin, Berlin, Germany; [2]Experimental Biophysics and Space Sciences, Institute of Experimental Physics, Freie Universität Berlin, Berlin, Germany.

The subsurface ocean of Saturn's icy moon Enceladus is a prime target in the search for extraterrestrial life. The ocean provides liquid water, organic chemistry and energy from hydrothermal activity. At the south pole, water freezes at the ocean surface and is ejected into space where it can be analyzed by impact ionization mass spectrometers on space probes. Thus, putative cells must grow near the surface or be transported upwards from deeper habitats.

In this project, we simulate the first scenario with the bacterium *Rhodonellum psychrophilum*. At its surface, the ocean is likely stratified by a salt-depleted layer with NaCl concentrations of 0.5 – 2 M, water temperatures around 0 °C, and pH 9-11. *R. psychrophilum* grows optimally at pH 10, 1 M NaCl and 5 °C, but can sustain 0 °C. As an aerobic chemoheterotroph, it would rely on transport of radiolytic oxygen from the icy surface and organic carbon from hydrothermal sites at the ocean floor.

To create putative biosignatures of an ocean surface inhabitant, we will grow *R. psychrophilum* at surface conditions in an aerobic ocean simulant. We simulate the detection by impact ionization in space with Laser Induced Liquid Beam Ion Desorption Time of Flight Mass Spectrometry.