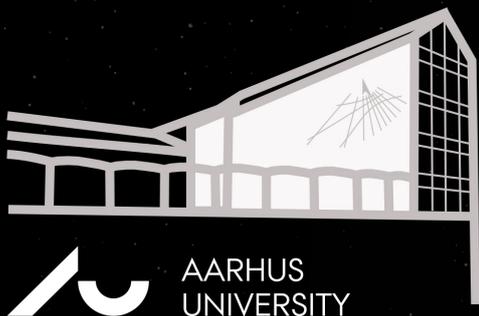


EANA 2017

European Astrobiology Network Association Exoplanets

14 -18 August 2017
Aarhus University
Denmark



STELLAR ASTROPHYSICS CENTRE
sac.au.dk/EANA17



Subject to errors and alterations!

Contents

Contents	1
1 Foreword	3
I Talks	5
2 Talks: Exoplanets and solar system bodies	7
A. Azua-Bustos: Have we found evidence of life on Mars using fractal complexity analyses?	8
G. Cataldi: Searching for biosignatures in exoplanetary impact ejecta	9
N. Georgakarakos: Are giant planets good neighbors for habitable worlds?	10
C. Gros: Are most habitable planets oxygen worlds? The prospects for indigenous and terrestrial life around M dwarfs.	11
M. Ishizuka: IRD - InfraRed Doppler instrument for the Subaru telescope	12
J. Jehlicka: Evaluating mineralogy and microbial colonizations of rocks using miniature Raman spectroscopy: training for Martian missions ?	13
L. Kaczmarek: Can tardigrades theoretically survive on Mars or on some of the recently discovered exoplanets?	14
K. M. Kinch: Geologic reconnaissance for sample collection on Mars using the Mastcam-Z on NASA's 2020 Mars rover mission.	15
K. G. Kislyakova: Induction heating of planetary interiors	16
H. Kjeldsen: Fantastic exoplanets and how to find them	17
P. E. Laine: White Dwarfs and Icy Worlds - Evolving Habitability	18
M. B. Madsen: VISIR References for SuperCam Calibration Target for NASA's Mars 2020 Rover	19
R. V. Nielsen: Accumulation of dust particles in a high efficiency particulate air (HEPA) filter under simulated Martian conditions	20
L. Noack: Volcanism and outgassing of stagnant-lid planets: Implications for the habitable zone	21
T. Šantl-Temkiv: Biological ice nucleation in clouds as a novel atmospheric biosignature	22
E. Szuszkiewicz: Second-order mean-motion resonances in a system of two low-mass planets	23
C. von Essen: Current challenges to find life in other planets	24
3 Talks: Experiments	25
S. Bagh: Systems biology unfolds novel cellular, metabolic and disease signatures and networks in microbes and human cells in microgravity	26
E. N. Bak: Effects of wind driven saltation on the survival of bacteria on Mars	27
M. Baqué: Preservation of carotenoids in cyanobacteria and green algae after space exposure: a potential biosignature detectable by Raman instruments on Mars	28
K. Beblo-Vranesevic: Survival of MASE strains under different aspects of simulated Martian conditions	29
D. Billi: Endurance of desert-cyanobacteria biofilms to space and simulated Mars conditions during the EXPOSE-R2 space mission	30
C. S. Cockell: Mars Analogues for space exploration – A summary of results	31
R. de la Torre Noetzel: Survival of lichens on the ISS-II: ultrastructural and morphological changes of <i>Circinaria gyrosa</i> after space and Mars-like conditions	32
J. Heinz: Enhanced Microbial Survival in Brines at Subzero Temperatures	33

Yuko Kawaguchi: 500 μm cell-aggregate of <i>Deinococcus</i> spp. was sufficient to survive after one-year exposure on ISS orbit in Tanpopo mission.	34
M. Malki: Comparative resistance of subsurface <i>Tessarococcus</i> isolates from the Iberian Pyrite Belt to simulated Martian conditions	36
R. L. Mancinelli: Using a spinning satellite to determine the effect of gravity on ecosystem N-cycling	37
H. Mita: First one year exposure results of organic compounds in Tanpopo mission	38
S. Ohno: The Biopause Project: Balloon Experiments for Sampling Stratospheric Bioaerosol	39
S. Onofri: The BIOMEX space experiment:, biosignatures detected after ground-based Science Verification Tests (SVT) in space and simulated Mars conditions	40
A. Papadopoulos: Tolerance of lichen-associated bacteria to astrobiological relevant conditions	41
P. Rettberg: MEXEM – Mars Exposed Extremophile Mixture – a space experiment to investigate the capability of anaerobic organisms to survive on Mars	42
P. Schwendner: Metabolic response of <i>Yersinia intermedia</i> MASE-LG1 to osmotic stress	43
4 Talks: Prebiotic chemistry and organics	45
W. Erdmann: Influence of hypmagnetic conditions on Earths organisms in the context of different variants of panspermia theory.	46
S. Jheeta: Space Travel: Challenges Ahead	47
T. P. Kee: Towards a Generalized Theory of Living	48
K. Kobayashi: Is the Strecker Synthesis a Major Formation Pathway of Amino Acids in Space?	49
H. L. Pleyer: A Novel Wet–Dry Apparatus for Simulating Prebiotic Hydration–Dehydration Cycles under Strictly Anaerobic Atmospheres	50
M. Polgári: Microbial mediation of minerals –terrestrial or parent body processes?	51
II Space Factor	53
5 Space Factor: Space Factor Contest	55
D. Boy: Abundance of radiation-resistant bacteria along an aridity gradient in the Atacama Desert – Are radiation- and desiccation resistance connected from the habitat perspective?	56
A. V. Dass: Hydrogels	57
J. Livingston: 200 Candidates and Validated Planets from Year Two of K2	58
B. J. A. Mooij: Time-resolved Raman spectroscopy for the detection of biomarkers in layered samples	59
M. Musariri: The Irradiation of Pure Methanol (CH_3OH) Ices at 30 K using 1 keV Electrons	60
P. Nauny: Dry riverbed in the Atacama desert: a depth profile analysis for biosignatures	61
F. Niloofar: Survival of halophilic archaeon <i>Halovarius luteus</i> gen. nov., sp. nov., to desiccation, simulated Martian UV radiation and vacuum in comparison to <i>Bacillus atrophaeus</i>	62
T. Omairi: Investigating the transfer and survivability of microbial cells within the stratosphere	63
A. B. Price: Autotrophy and biomineralisation of nitrate-dependent iron oxidisers on Mars-relevant mineral substrate	64
Uyama Taichi: Search for Exoplanet around Young Stellar Objects	65
C. Verseux: Cyanobacteria as a substrate for heterotrophs – Implications for biological life-support systems on Mars.	66

III Posters	67
6 Posters: Exoplanets and solar system bodies	69
Michaël GILLON: Characterising ultra-cool dwarfs on the search for exoplanets: the SPECULOOS project and the TRAPPIST-1 system	70
I. Gyollai: Microbially mediated siderite as candidate for possible carbonate impact ejecta	71
J. M. Kashyap: Active and cryptobiotic tardigrade survivability indexes for exoplanets	73
T. Kozakis: UV Environments and Biosignatures of Earth-Like Planets Orbiting White Dwarfs	74
P. Nørnberg: THE MARTIAN DUST STRUCTURE AND MINERALOGY	75
A. Valantinas: Lunar wrinkle ridges reveal tectonic activity in the past 100 million years	76
N. Georgakarakos: Three-dimensional climate modelling of a terrestrial world under the gravitational perturbations of a close-in Jupiter	77
Y. Yang: Subaru/HiCIAO Near-Infrared High-contrast Polarimetry Observation Towards Disk around Binary System GG Tau A	78
7 Posters: Experiments	79
T. Backhaus: Primary results of the analysis of the lichen <i>Buellia frigida</i> after 1.5 years of space exposure during the BIOMEX project	80
D. Billi: Detection of biomarkers of the desert cyanobacterium <i>Chroococidiopsis</i> after the EXPOSE-R2 space mission	81
P. Cabezas: Dissemination and Communication Activities for Mars Analogue Re- search	82
V. S. Cheptsov: Duration of Microorganisms Survival in Cryopreserved State in Martian Regolith	84
L. Garcia-Descalzo: Preservation and detection of biomarkers in mineralized com- munities and its potential link to the variations in ORP	85
S. Jheeta: Hypothesis: ncRNA - cellular activity controller?	86
A. Karachitos: What links tardigrades, mitochondria and space travels?	87
A. Kereszturi: Field works in Morocco to support ExoMars rover to understand the habitability of Mars	88
D. Maus: Brines formed by Deliquescence as a Habitat for Methanogenic Archaea	89
P. Nauny: Dry riverbed in the Atacama desert: a depth profile analysis for biosig- natures	90
C. Panitz: The BOSS Experiment of the EXPOSE-R2 Mission: Biofilms versus planktonic cells	91
R.-S. Taubner: Trace Elements of methanogens in an astrobiological context	92
F. Westall: Analogues for a European Extraterrestrial Sample Curation Facility	93
H.-A. Stavarakakis: An electrokinetic concept for remobilising water masses and creating essentials for the colonization of Mars	94
8 Posters: Prebiotic chemistry and organics	95
K. Albdeery: Abiogenically Relevant Self-Assembly Processes in Silica Hydrogels	96
Christian Anders: Molecular dynamics simulation of reactive surface impacts	97
W. Erdmann: Panspermia – unifying of the nomenclature.	98
S. Gálvez: Small glycine-peptides on pyrite surface investigated by XPS	99
A. Kauko: Eukaryote Specific Folds: Parts of the Whole	100
D. A. Skladnev: Nanobiotechnological approach for detection of life in extraterres- trial water and ice environment	101
I. Wolf: Laboratory Simulation of the Thermal Racemization of L-Alanine in Tide Pools of Primordial Volcanic Islands	102

S. Wolf: OREOCube (ORganics Exposure in Orbit): In-Situ Spectroscopy of Organic Compounds on the International Space Station 103

Foreword

1

The EANA 2017 workshop in Aarhus, Denmark

It is with pleasure that we welcome you to Aarhus University, the second-oldest and second-largest university in Denmark. Most of the university's yellow-brick buildings are located on the picturesque campus, which is situated in a hilly area, with a moraine valley full of large oak trees and a stream that flows into two small lakes.

Aarhus University is a centre of tradition and innovation, discussion and debate, cooperation and concentration, and we are pleased to be able to share these with others. We value the contributions which international students and researchers make to this tradition and to the cultural and social diversity which enhances the academic experience.

The EANA 2017 conference is hosted by The Stellar Astrophysics Centre (SAC), a Centre of Excellence funded by the Danish National Research Foundation and located at the Department of Physics and Astronomy at Aarhus University. The purpose of SAC is to study the stars and their planetary systems. SAC seeks to produce a complete picture of the structure, atmosphere and magnetic activity of the stars and the so-called exoplanets in their orbit. These studies are based on combining new observations from the Kepler space telescope and data from the SONG network of telescopes. In addition, SAC researchers are highly involved in the development of new and existing missions to explore these unknown worlds.

Although the SAC core group is located at the Department of Physics and Astronomy at Aarhus University, SAC is embedded in a strong national and international network linking together research institutes in Europe, USA and Australia. SAC is pleased to host EANA 2017, because of the strong interest SAC researchers have in exoplanets and their possible habitability.

We look forward to an exiting and fruitful conference and welcome you to Aarhus and the Stellar Astrophysics Centre.

Talks

Talks: Exoplanets and solar system bodies

2

Have we found evidence of life on Mars using fractal complexity analyses?

A. Azua-Bustos¹

C. Vega-Martínez²

(1) Centro de Astrobiología, CSIC-INTA, Madrid, Spain.

(2) Instituto de Astrofísica de La Plata (CCT La Plata, CONICET – UNLP), Argentina.

It is highly probable that Martian lifeforms may be entirely different to the one evolved on Earth. This is a significant constraint for the life-detecting instruments that were sent and may be sent to the red planet, as how could we detect life as “we don’t know it”? Here we argue that all lifeforms in the Universe must decrease their internal entropy at the expense of free energy obtained from its surroundings. As entropy quantifies the degree of disorder in a system, any envisioned lifeform must have a higher degree of order than its supporting environment. Here we show that by using fractal mathematics analysis alone, one can readily quantify the degree of entropy difference (and thus, their structural complexity) of living processes as distinct entities separate from its similar abiotic surroundings. This approach allowed us to examine the complexity of sedimentary processes on Mars, and our results suggest that these may have been influenced by life at some point during its formation.

Searching for biosignatures in exoplanetary impact ejecta

G. Cataldi^{1,2}

A. Brandeker^{1,2}, Ph. Thebault³, K. Singer⁴, E. Ahmed^{2,5,6}, B. L. de Vries^{1,2,7}, A. Neubeck^{2,6},
G. Olofsson^{1,2}

- (1) AlbaNova University Centre, Stockholm University, Department of Astronomy, SE-106 91 Stockholm, Sweden.
- (2) Stockholm University Astrobiology Centre, SE-106 91 Stockholm, Sweden.
- (3) LESIA-Observatoire de Paris, UPMC Univ. Paris 06, Univ. Paris-Diderot, France.
- (4) Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, USA.
- (5) Royal Institute of Technology (KTH), Science for Life Laboratory, SE-17121 Solna, Sweden.
- (6) Stockholm University, Department of Geological Sciences, SE-10691 Stockholm, Sweden.
- (7) Scientific Support Office, Directorate of Science, European Space Research and Technology Centre (ESA/ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands.

Detecting life over astronomical distances is a challenging problem. To date, most efforts have concentrated on how to detect changes by life in planetary atmospheres. In this talk, I will instead focus on the possibility of characterising the surface biophere of an exoplanet by studying debris ejected from a giant impact. I present results from a study recently published in *Astrobiology*, where we estimate under what conditions characterisation would be possible. While we find that debris from such impacts can indeed be detected with current instrumentation, characterisation will have to await future developments.

Are giant planets good neighbors for habitable worlds?

N. Georgakarakos¹

S. Egg^{1,2}, I. Dobbs-Dixon¹

(1) Division of Science, New York University Abu Dhabi, United Arab Emirates.

(2) Jet Propulsion Laboratory, California Institute of Technology, USA.

Today planets with sizes comparable to that of the Earth revolving around stars other than our Sun are an observational fact. An issue of great scientific as well as public interest is where exactly Earth-like planets capable of harboring liquid water are likely to be found. If giant planets are present in the same system, they interact with terrestrial worlds in multiple ways. In particular, the gravitational interaction and the ensuing changes in the Earth-like planet's orbit change the amount of light the latter receives. This in turn influences the terrestrial world's habitability. Investigating all exoplanetary systems known to date that host a main sequence star and a giant planet we show that the presence of 'giant neighbors' can reduce a terrestrial planet's chances to remain habitable substantially, even if both planets have stable orbits. Additionally, we provide constraints on where giant planets cease to affect the habitable zone size significantly. Systems satisfying those constraints can be considered prime targets in the search for habitable worlds. Our study suggests that in the currently known population, systems containing hot Jupiters are more conducive to sheltering habitable planets, if the latter survive or form after the migration phase.

Are most habitable planets oxygen worlds? The prospects for indigenous and terrestrial life around M dwarfs.

C. Gros¹

(1) Institute for Theoretical Physics, Goethe University Frankfurt, Germany.

Introduction. Abiotic oxygen builds up generically on terrestrial habitable zone M dwarf planets during the initial runaway greenhouse state. A massive initial oxygen atmosphere is however likely to preempt in situ prebiotic evolution and hence the development of life per se. Otherwise habitable planets could hence turn out to be devoid of indigenous lifeforms.

It may on the other side be possible to launch within the next 100 years robotic interstellar probes capable to establish on selected exoplanets an ecosphere of bacteria and unicellular eukaryotes. Hitherto sterile oxygen planets may hence offer alternative evolutionary pathways for terrestrial life. Alternative candidates for initiating a Genesis process would be brown-dwarf planets experiencing a continuously inward-moving habitable zone.

Oxygen planets. The extended pre-main sequence Kelvin-Helmholtz contraction phase lasting only about 10 Ma for sun-like stars may extend up to several Ga for late M dwarfs. The far and extreme UV radiation produced by the young host star leads then to a massive photolysis of the H_2O present in the wet stratosphere of the greenhouse state and with it to the escape of hydrogen to space. The habitable zone planets of the TRAPPIST-1 system are expected to have lost this way several Earth's oceans' worth of water.

One hence expects that most of the projected tens of billions of habitable zone M dwarf planets present in the galaxy will be rock dry with O_2 pressures of several tens to hundreds atmospheres. A substantial amount of water may be retained however for suitable orbital parameters, not too long greenhouse states and a substantial initial reservoir of volatiles.

Abiogenesis on oxygen planets. Life may have originated on earth within sub-oceanic hydrothermal vents akin to the 'lost city'. These vents act as natural bioreactors in which redox reactions like $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ power a rich palette of prebiotic organic reactions. The restricted geometries of the pores allow furthermore for concentration processes and hence, possibly, for the formation of protocells. The destructive interference of the very high concentrations of dissolved oxygen present in the oceans of oxygen planets will however preempt the formation of prebiotic reaction cycles and hence of life itself.

Genesis project. The search for non-terrestrial life is a core motivation for exoplanetary science. The possible existence of billions of habitable zone but sterile oxygen planets warrants in addition to consider the reverse perspective. Passive deceleration via magnetic sails is furthermore possible for interplanetary missions when time is not a limiting factor, as it would be the case for missions aiming to seed Genesis candidate planets (C. Gros: *Developing ecospheres on transiently habitable planets: the Genesis project*. Astrophysics and Space Science bf 361, 324, 2016).

IRD - InfraRed Doppler instrument for the Subaru telescope

M. Ishizuka¹

T. Kotani^{2,3}, J. Nishikawa^{2,3}, T. Kurokawa^{2,4}, M. Tamura^{1,2,3}

- (1) Department of Astronomy, University of Tokyo, Japan.
- (2) National Astronomical Observatory of Japan, Japan.
- (3) Astrobiology center, Japan.
- (4) Tokyo University of Agriculture and Technology.

More than 3000 exoplanets have been discovered, and the next goal is the discovery of many Earth-like planets in the Habitable Zone. Radial Velocity (RV) method is one of the most successful techniques to search for exoplanets, though extreme high precision is required to detect such small planets; ~ 10 cm/sec RV measurement precision is required to detect Earth-like planets in the HZ around a Solar-type star, and this precision is still below the current achievable precision. M dwarfs are promising targets to search for Earth-like planets, because their RV variation induced by planets is much larger than that of the Sun-like stars. Thus we can detect the Earth-like planets in the HZ with current RV measurement precision (~ 1 m/sec). Since M dwarfs emit almost all energy at near-infrared (NIR) wavelengths, observations at NIR wavelengths are effective. Under these circumstances, we have developed the InfraRed Doppler instrument (IRD) for the Subaru 8.2m telescope. IRD is a fiber-fed spectrograph to search for exoplanets around nearby M dwarfs by high precision RV method. Its wavelength coverage is 0.97-1.75 μ m with a 70000 spectral resolution. The 8.2m diameter of the Subaru telescope enables us to observe faint late-M dwarfs. A dedicated laser frequency comb has also been developed as a precise wavelength calibration. Our laboratory test has demonstrated that the combination of this comb and the spectrometer can achieve a RV measurement precision of ~ 1 m/sec. The main goal of IRD is detection of ~ 50 Earth-mass exoplanets around nearby M dwarfs. IRD also has a capability of characterizing atmospheres of bright exoplanets which can be a prototype of future characterization of Earth-like planets in the E-ELT era. IRD was installed at the summit of the Mauna Kea and engineering observations are going on.

Evaluating mineralogy and microbial colonizations of rocks using miniature Raman spectroscopy: training for Martian missions ?

J. Jehlicka¹

A. Culka¹

(1) Institute of Geochemistry, Mineralogy and Mineral Resources, Charles University, Czech Republic.

Raman spectroscopy has been repeatedly proposed as a powerful technique to detect biological markers for Mars lander exobiological missions. It was suggested to carry-out training on Earth, in the frame of environments proposed as Martian analogues. ESA as well as NASA will include Raman spectrometric devices as key instruments in the forthcoming robotic Martian missions, Exomars and Mars 2020. In this presentation an overview of recent achievements for detecting minerals and biomolecules using miniature Raman spectrometers is given. Nowadays miniature and lightweight Raman spectrometers as well as flight representative Raman instruments play an important role for detection and discrimination of minerals and biomolecules onsite. This has been demonstrated in numerous studies of common and extreme rocky environments on Earth. Excitation wavelength selection is extremely important for accessing quality Raman spectral data from microbiological samples. Detecting biomarkers of extremophiles using such an analytical strategy can help us learn about microbes' survival and mode of conservation of organics. Excellent identification of pigments using Raman bands positions of the principal features was achieved also directly on cultures of halophilic microorganisms including Archaea. With a handheld spectrometer (532 nm excitation) (Rigaku), Raman spectra of pigments in autotrophic (cyanobacteria and purple sulfur bacteria) and heterotrophic halophilic microorganisms (Archaea of the family Halobacteriaceae and *Salinibacter*) were recorded. Common and less common carotenoids, including bacterioruberin (*Haloferax*, *Haloarcula* and *Halobacterium*) (Archaea), salinixanthin (*Salinibacter*) (Bacteroidetes), and spirilloxanthin-like (*Ectothiorhodospira*) (Gammaproteobacteria) were detected in cell pellets of laboratory cultures. For carotenoid detection the advantage of using Resonance Raman effect (here 532/514 nm) can be seen as a main advantage. Mobile Raman instrumentation can be used to investigate past environments (mineralogy) as well as possible organics conserved in the rocks. Several examples are highlighted here to show potential and limits of the approach. Raman analysis of the colored microbial community layers in a benthic gypsum crust in the saltern evaporation ponds identified myxoxanthophyll and echinenone carotenoids as well as spirilloxanthin in different layers. Endolithic colonizations are often studied in desert areas (i.e. Atacama). Raman spectroscopy was successfully used to detect sunscreen pigments in cyanobacteria from Atacama - examples of extremophiles living in extremely dry areas under high UV exposition. Pigments of snow algae were detected onsite at glaciers under different exposition conditions. A new type of mobile Raman spectrometric system appeared recently on the market. New modes of eliminating fluorescence by using this "Sequentially Shifted Excitation Raman Spectrometer" (pSSE-RS) are introduced here as well.

Can tardigrades theoretically survive on Mars or on some of the recently discovered exoplanets?

Ł. Kaczmarek¹

J. M. Kashyap²

- (1) Department of Animal Taxonomy and Ecology, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University in Poznań, Poznań, Poland.
- (2) Department of Physics, Jyoti Nivas College, Bengaluru, India.

It is known, that some microorganisms like bacteria, Archaea, algae or fungi can survive in harsh conditions which are present on other planets and/or moons (e.g. on Mars). But would it be also possible in respect of higher organisms, like animals? More precisely, a microscopic invertebrates - tardigrades? Mars, with almost lack of atmosphere, very low atmospheric pressure and temperatures, the lack of liquid water and high doses of cosmic, ionizing and UV radiation, is rather a hostile place for Earth invertebrates. On the other hand, it is still probably the most friendly place (excluding the Earth) for terrestrial organisms in the Solar System. As it was shown in numerous studies in the past, the best candidates, to survive in Martian conditions, belong to a few groups of cryptobiotic invertebrates i.e. nematodes, rotifers and of course tardigrades. However, it should be also remember that up to now almost 3500 exoplanets have been found (https://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html). They represent very wide range of physical and chemical conditions. Therefore, it can be also asked, if some Earth extremophiles can survive on e.g. recently discovered TRAPPIST-1 planets where the physical and chemical conditions would be also similar to the Earth? The Phylum Tardigrada (water bears) consists of over 1,200 species (Degma et al., 2009–2017) that inhabit almost all terrestrial, freshwater and marine environments throughout the world from the ocean depths to highest mountains (Nelson et al., 2015). Tardigrades, as one of the toughest metazoans on Earth and a model multicellular organisms are often used in studies on survivability in the extreme conditions (Guidetti et al., 2012). Tardigrades owe this remarkable resistance to adverse conditions to their ability to enter into cryptobiosis. During this state, metabolic processes significantly decrease or even completely stop. Many experiments showed that water bears have significant resistance to a number of environmental stressors like lack of liquid water, low and high temperatures and pressures, irradiation and many chemicals. Now we can ask, if this is enough to survive on Mars or on some exoplanets?

Geologic reconnaissance for sample collection on Mars using the Mastcam-Z on NASA's 2020 Mars rover mission.

K. M. Kinch¹

M. B. Madsen¹, J. F. III Bell², J. N. Maki³

- (1) Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, kinch@nbi.ku.dk.
- (2) School of Earth & Space Exploration, Arizona State University, Tempe, Arizona, USA.
- (3) Jet Propulsion Laboratory, Pasadena, California, USA.

Nasa's 2020 Mars rover will be a large, capable rover built on the same basic design as the Curiosity rover that was launched in 2011 and is currently exploring Gale Crater on Mars. The 2020 rover will land on Mars in 2021 carrying a payload of seven scientific instruments designed to investigate the geomorphology, geochemistry and mineralogy of a landing site at different scales as well as look for subsurface ice and potential signatures of past life. An important goal of the mission is to collect and cache a selection of rock and regolith samples for future return to Earth. The Mars 2020 rover is thus the first step in a multi-step process to achieve Mars sample return, a long-standing goal of the Mars science community.

The Mastcam-Z camera system consists of a pair of mast-mounted zoom-capable cameras. Mastcam-Z will assist rover operations through fast production of stereo images and digital terrain models to support planning of rover traverses and placement of arm-mounted instruments. Mastcam-Z will also be an important asset for the missions science investigations through production of panoramas and high-resolution imaging of fine-scale textures in rocks and soil and through multispectral imaging for mineralogy and atmospheric science.

The Mastcam-Z can acquire multispectral observations through 11 different narrow-band filters spanning 450 nm - 1000 nm. A number of minerals common in the martian environment may be discerned using the Mastcam-Z filter set. This capability will help the rover map compositional variations across the local terrain as well as bridge the gap between images and spectra acquired from orbit and in-situ mineralogical and geochemical measurements performed by other instruments on the payload. Mastcam-Z will be crucial for placing in-situ observations and acquired samples in a wider geological context and for selecting the best, most diverse and scientifically compelling set of samples.

Correct interpretation of multispectral observations of the martian terrain requires conversion from units of radiance to reflectance for comparison with e.g. laboratory spectra of mineral samples, i.e. it requires "dividing out" by an estimate of incoming solar illumination. This is hard to estimate because of constantly varying atmospheric conditions (dust load, clouds) and because the optical properties of the surface itself influence the illumination conditions through multiple ground-atmosphere scatterings.

Mastcam-Z relies on a set of rover-deck-mounted calibration targets containing patches of ceramic materials with well-characterized bi-directional reflectances to solve this problem. The targets contain magnets in order to reduce atmospheric dust deposition and dust-correction software is employed to handle optical effects of what dust is still present.

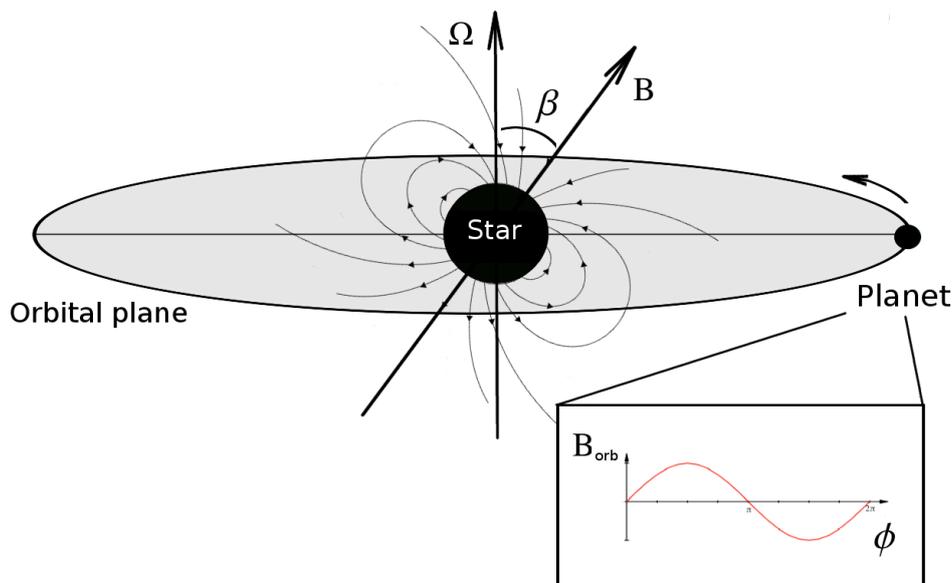
Induction heating of planetary interiors

K. G. Kislyakova^{1,2}

L. Noack³, C. P. Johnstone¹, V. V. Zaitsev⁴, L. Fossati², H. Lammer², M. L. Khodachenko²,
P. Odert², M. Güdel¹

- (1) University of Vienna, Department of Astrophysics, Türkenschanzstrasse 17, A-1180 Vienna, Austria.
- (2) Space Research Institute, Austrian Academy of Sciences, Schmiedlstrasse 6, A-8042 Graz, Austria.
- (3) Royal Observatory of Belgium, Department Reference Systems and Planetology, Avenue Circulaire 3, 1180 Uccle, Belgium.
- (4) Institute of Applied Physics, Russian Academy of Sciences, 46 Ul'yanov Street , 603950, Nizhny Novgorod, Russia.

We present a work which addresses the induction heating of exoplanets orbiting strongly magnetized late M dwarfs. Low-mass M dwarfs are very numerous in the Universe and are observed to often host exoplanets with the masses comparable to that of the Earth. These stars often have strong magnetic fields of simple topology. In our work, we consider a dipole field of the host star. If the stellar dipole axis and the rotation axis are inclined with respect to each other, the planets at their orbital locations are embedded in a constantly varying magnetic field. This field will induce currents inside the conducting planetary mantle, which will consequently dissipate and heat the planetary interiors. We show that this heating can be strong enough to melt the planetary mantle on a geological time scale and power extreme volcanic activity at the planetary surface. We calculate the induction heating and model the corresponding magmatic effects for stagnant-lid exoplanets. We show that the effect is significant for M dwarfs with the magnetic fields of approximately 500 G and stronger and a fast rotation period of a few days and shorter. Since the planets in the habitable zones are also affected by this heating mechanism, we conclude that it has to be taken into account while addressing the evolution of the exoplanets orbiting such stars.



Fantastic exoplanets and how to find them

H. Kjeldsen¹

(1) Stellar Astrophysics Center, Department of Physics and Astronomy, DK 8000 Aarhus C, Denmark.

One of the fastest developing fields of astrophysics is the study of planets orbiting other stars than our Sun, extra solar planets or exoplanets for short. These distant worlds display some surprising characteristics, unknown from our own solar system. Some exoplanets orbit their stars in only a few days, others travel in extremely elliptical orbits, and some orbit over stellar poles. However, not only the orbital characteristics, also the planets themselves have surprised us. The atmospheres of some exoplanets reflect as little light as coal, and some planets have densities as low as cork. We have discovered planets with sizes intermediate between Earth and Neptune ('Super-Earth' planets), a class of planets absent in the Solar System. Currently, the planets about which we can learn the most are those, which transit their host stars. Their orbits are seen nearly edge on, and we observe a periodical dimming, when they move between us and their star allowing for detailed investigations of their orbital characteristics, internal structure and atmospheres. In this lecture, I will discuss how we search for and study the properties of exoplanets using telescopes on ground and in space. The main focus will be on determination on properties of exoplanets and their atmospheres.

White Dwarfs and Icy Worlds - Evolving Habitability

P. E. Laine¹

(1) Department of Physics, University of Jyväskylä, Finland.

White dwarfs are the final state of stellar evolution of the most stars in the Milky Way. These stars (like our Sun) have long hydrogen-fusing steady period during terrestrial planets could be in habitable zone at few AU distance. At the end of the steady period, they undergo expansion to red giant phase, when inner planets are engulfed by the star, thus ending their habitability. However, during this period potential icy moons of the gas giant planets (exo-Jupiters) in outer orbits could still remain habitable (if these gas giants remain entire). After a red giant phase, the star will shed its outer layer and leave behind the core, the white dwarf. Could the icy worlds in outer system remain habitable during the whole lifespan of the star, from main sequence star to red giant, outer layer escape to slowly cooling white dwarf? If so, these icy worlds could then have at least tens of billions of years for life to emerge and evolve. This paper will evaluate the evolving habitability of these icy worlds.

VISIR References for SuperCam Calibration Target for NASAs Mars 2020 Rover

M. B. Madsen¹

K. M. Kinch¹, J. A. Manrique², F. Rull², G. L. Reyes², O. Gasnault³, A. Cousin³, P.-Y. Meslin³, S. Maurice³, C. Ortega⁴, I. Sard⁴, C. Castro⁴, J. Frydenvang⁵, T. Fouchet⁶, R. C. Wiens⁷

- (1) Niels Bohr Institute, University of Copenhagen, Denmark.
- (2) Centro de Astrobiología, Unidad Asociada CSIC-UVA, Cristalografía y Mineralogía Facultad de Ciencias, University of Valladolid, Spain.
- (3) Institut de recherche en astrophysique et planetologie (IRAP), Toulouse, France.
- (4) Added Value Solutions (AVS), Elgoibar, Spain.
- (5) Natural History Museum of Denmark, University of Copenhagen, Denmark.
- (6) Observatoire de Paris, Paris, France.
- (7) Los Alamos National Laboratory, Los Alamos, New Mexico.

The main purpose of NASAs Mars 2020 Rover is to select, characterize, collect and cache a suite of samples from the Mars surface, and to store these cached samples for return to Earth by a later mission. Samples selected should advance our knowledge about the history of the surface of Mars and/or about the potential for signals originating from biological activity.

One of the tools on board to help select the best samples is the SuperCam remote sensing instrument suite, which is a more advanced development of the ChemCam instrument suite on board NASAs Curiosity mission. SuperCam will include laser induced breakdown spectroscopy (LIBS) with remote Raman spectroscopy, high resolution color imaging, acoustic sensing and visible and infrared (VISIR) reflectance spectroscopy. In order to maintain preflight calibration of the instruments in this suite a set of reference targets are built into a suitable holder providing an appropriate posture of the targets and protection of these during the vibrations and shocks of launch and landing.

Because of the small footprint of the LIBS laser spot, about 250 microns, the reference targets for chemical and mineralogical calibrations need to be homogeneous to less than 25 microns. In order to achieve these requirements a flash sintering process has been used to generate reference samples based on homogenized powders of minerals.

Five reference target elements, designed, built and assembled at the Niels Bohr Institute, will employ permanent magnets to help mitigate dust contamination of the references for which shooting by the LIBS laser is not allowed. A set consisting of red, green, cyan and white ceramic targets and a target painted with an IR-black paint will serve as reference targets for the high resolution color imager and for the visible and infrared spectrometers.

The laser, telescope, IR spectrometer, and color camera is provided by CNES, while the LIBS, Raman, and VIS spectrometers and data processing units are built and delivered by Los Alamos National Laboratory (LANL). The main sample holder of the calibration target assembly is provided by University of Valladolid, Spain, with elements provided by LANL, several French and Spanish institutions as well as by the Niels Bohr Institute, University of Copenhagen, Denmark. The contributions from NBI are made possible through a grant from the Carlsberg Foundation (CF16-0981).

Accumulation of dust particles in a high efficiency particulate air (HEPA) filter under simulated Martian conditions

R. V. Nielsen¹

(1) Niels Bohr Institute, University of Copenhagen, Denmark.

NASA's Mars 2020 Rover mission will carry the Mars Oxygen In-situ resource utilization Experiment (MOXIE) a part of its payload. MOXIE is a demonstration experiment that will produce oxygen directly from the Martian atmosphere by solid state electrolysis, forming O_2 and CO from the CO_2 in the Martian atmosphere. Generation of oxygen in-situ will be a crucial technology enabling human exploration of Mars by making available a large supply of oxygen for breathing and as an oxidant for the fuel of the return rocket. While the synthesis in itself is a well-known technology on Earth, the Martian environment presents extra challenges both in compression of the thin Martian atmosphere and in protecting the machinery from damage from Martian atmospheric dust.

I will present the design of an experiment to monitor the accumulation of dust particles in a high efficiency particulate air (HEPA) - filter under Martian conditions. It will be tested in a wind tunnel with Martian conditions. If successful it may be installed as a supplement to MOXIE which uses a similar filter to remove dust from the inlet gas, but the MOXIE filter is not visible for onboard cameras to observe the accumulation of dust particles. My experiment could be installed in a location visible from a camera on the robotic arm of the rover. The external filter experiment will have three separate compartments each showing different methods of accumulation; suction created by the Venturi effect, magnetic attraction and finally a control with no attractive effects:

The Venturi effect: The focus of my project has been on developing this method. This effect will be achieved by having an aerodynamically shaped constriction placed on each side of the filter-mount compartment. The idea is that the Venturi Effect will create a sufficiently low pressure under the filter, to create a clearly visible pattern of attracted dust particles. A full pressure drop of 600Pa at average atmospheric conditions has been set to occur at 4.5m/s entry wind velocity parallel to the Venturi-channel. This has resulted in a constriction area ratio of 54 given the dimensions; entry 30mm x 20mm and exit 8.0mm x 1.4mm. These dimensions lead to a Reynolds number of around 3000, which might introduce some turbulence into the flow. However, most often wind direction will not be parallel to the Venturi-channel.

Furthermore, the experiment could be adapted to accumulate dust in other materials than HEPA-filters. This could for instance be a substrate mesh to investigate certain chemical reactions by compounds carried by the dust.

While the search for extant life on Mars will undoubtedly be heavily complicated by the presence of human explorers, the search for potential biofossils will be massively more effective if conducted with "boots on the ground" and the MOXIE experiment will demonstrate a crucial technology to enable this.

Volcanism and outgassing of stagnant-lid planets: Implications for the habitable zone

L. Noack^{1,2}

A. Rivoldini¹, T. Van Hoolst¹

(1) Royal Observatory of Belgium, Brussels, Belgium.

(2) Freie Universität Berlin, Germany.

Rocky exoplanets are typically classified as potentially habitable planets, if liquid water exists at the surface. The latter depends on several factors like the abundance of water but also on the amount of available solar energy and greenhouse gases in the atmosphere for a sufficiently long time for life to evolve. The range of distances to the star, where surface water might exist, is called the habitable zone. Here we study the effect of the planet interior of stagnant-lid planets on the formation of a secondary atmosphere through outgassing that would be needed to preserve surface water.

We find that volcanic activity and associated outgassing in one-plate planets is strongly reduced after the magma ocean outgassing phase for Earth-like mantle compositions, if their mass and/or core-mass fraction exceeds a critical value. As a consequence, the effective outer boundary of the habitable zone is then closer to the host star than suggested by the classical habitable zone definition, setting an important restriction to the possible surface habitability of massive rocky exoplanets, assuming that they did not keep a substantial amount of their primary atmosphere and that they are not in the plate tectonics regime.

Biological ice nucleation in clouds as a novel atmospheric biosignature

T. Šantl-Temkiv¹

M. Ling¹, S. Holm¹, M. Alsved², S. Grawe³, J. Jacobson², S. Hartmann³, H. Wex³, J. Löndahl²,
H. Kjeldsen¹, T. Boesen¹, K. Finster¹

(1) Aarhus University, Aarhus, Denmark.

(2) Lund University, Lund, Sweden.

(3) Institute for Tropospheric Research, Leipzig, Germany.

Recent cataloguing of planets orbiting other stars than our sun (exoplanets) established the ubiquitous presence of planets in our galaxy [1]. With the discovery of these planets arises the question of how life emerges and evolves throughout the universe. The exoplanetary atmospheres provide some of the most accessible evidence for the presence of biological activity on these planets. Metabolic gases have been commonly proposed as atmospheric biosignatures [2]. However, airborne microbes are also involved in cloud- and precipitation formation on Earth. Thus, meteorological phenomena may serve as alternative atmospheric biosignatures, for which appropriate observational techniques have yet to be developed.

The atmospheric part of the Earth's water cycle heavily relies on the presence of nucleating particles, which promote the condensation and freezing of atmospheric water, both potentially leading to precipitation. While cloud condensation nuclei are diverse and relatively common, ice nuclei are poorly understood and comparably rare airborne particles. According to current knowledge, most ice nucleation below -15°C is driven by the presence of inorganic dust particles, which are considered inactive at higher temperatures. Biogenic IN are the only reported particles that promote ice formation above -10°C . Some bacteria, e.g. *Pseudomonas syringae*, produce Ice Nucleation Active (INA) proteins that are most efficient ice nuclei currently known. These INA bacteria are common in the atmosphere, and may thus be involved in precipitation processes of mixed phase clouds [3]. We are investigating the relevance of bacterial INA proteins for atmospheric processes using laboratory studies of model bacterial species and isolated INA proteins.

We investigated stress-response genes of a model INA strain *P. syringae* R10.79, in order to understand its survival in the atmosphere. The response to simulated atmospheric conditions was investigated in the laboratory. These experiments revealed a high resistance of R10.79 to UVB radiation, freeze-thaw stress and aerosolization from liquid surfaces. In order to study isolated INA proteins, we sequenced the INA gene of R10.79. The INA gene was expressed in both its native form and in a modified form. Both proteins were purified and their physical and molecular properties were studied. We show that interaction between INA proteins and the size of their central domain are relevant for their ice nucleation activity. Our results are a significant step towards understanding the role of biological ice nucleation in large scale meteorological patterns, which may in future serve as novel biosignatures on exoplanets.

References

- [1] A. W. Howard, *Science* 340 (2013).
- [2] S. Seager, M. Schrenk, and W. Bains, *Astrobiology* 12(1) (2012).
- [3] O. Möhler, P. J. DeMott, G. Vali, and Z. Levin, *Biogeosciences* 4 (2007).

Second-order mean-motion resonances in a system of two low-mass planets

E. Szuszkiewicz¹

J. C. B. Papaloizou², Z. Cui¹

- (1) Faculty of Mathematics and Physics, University of Szczecin (Poland).
(2) DAMTP, University of Cambridge, United Kingdom.

It is well known that first-order mean-motion resonances are common outcomes of the convergent orbital migration of low-mass planets in gaseous protoplanetary discs (Papaloizou and Szuszkiewicz, 2005). The attainment and maintenance of these resonances by migrating planets in the terrestrial mass range have been extensively studied by means of hydrodynamic simulations, simple analytic modelling and N-body investigations. The number of planetary systems in which the period ratios are close to a commensurability is increasing thanks to an ongoing intensive search for planets from the ground and space. However, among the observed period ratios one can find not only the first-order commensurabilities but also those of the second-order, like for instance 5:3, 7:5 or 9:7. The latter are of course less numerous than first order resonances but for sure not less intriguing.

Are such resonant configurations easily induced by orbital migration? What are the conditions occurring in the protoplanetary disk which favour their formation? With these questions in mind we explore the attainment of the 9:7 resonance in a system which contains a pair of migrating low-mass planets. We have performed a series of hydrodynamical simulations with a variety of different initial disc parameters and planet mass ratios. We conclude from our investigations that the resonance capture is possible if the relative convergent migration is slow and the planets have moderate eccentricities.

We have compared our results with the simple analytic theory presented in the paper of Xiang-Gruess and Papaloizou (2015) which provides the conditions for the formation of the second order commensurabilities. It has been found that these conditions are consistent with our simulations. Moreover, our results are also accordant with the general model of resonance capture discussed in Mustill and Wyatt (2011).

References

- [1] Mustill, Alexander J.; Wyatt, Mark C. (2011), MNRAS 413, 554.
[2] Papaloizou, J. C. B.; Szuszkiewicz, E. (2005), MNRAS 363, 153.
[3] Xiang-Gruess, M.; Papaloizou, J. C. B. (2015), MNRAS 449, 3043.

Current challenges to find life in other planets

C. von Essen¹

(1) Stellar Astrophysics Centre, Department of Physics and Astronomy, Aarhus University.

Searching for and understanding planets orbiting other stars than our Sun is one of the foremost and most exciting fields of contemporary astrophysics. Indeed, for the last 20 years we have been characterizing alien worlds in great detail with the ultimate goal of finding life on other planets. The more than four thousand discovered planets orbiting other stars often show surprising characteristics, some of them not found in our own Solar System. With the main goal of finding life outside Earth, I focus my research in the characterization of the chemical elements of the atmospheres of hot Jupiters, planets as large as Jupiter but orbiting around their stars each few days. When these planets periodically block (transit) the stellar disk, they create a dim in light that we can use to learn a wealth about these systems. Lets picture the planet as a dark sphere, surrounded by an extremely thin layer, its atmosphere. During a transit event stellar light of a given wavelength will pass through this layer without interacting with it. Some other light will be absorbed by the atmospheric constituents, and the planet will appear larger than in the first case. Thus, observing transits in different wavelengths allows us to indirectly infer the chemical composition of their atmospheres. In this talk I will review the current status of the exo-atmospheric characterization, I will tell you about my own research, and I will close making special emphasis on the topics I believe can bring closer the fields of exoplanets and astrobiology.

Talks: Experiments

3

Systems biology unfolds novel cellular, metabolic and disease signatures and networks in microbes and human cells in microgravity

S. Bagh^{1,2}

S. Mukhopadhyay¹, R. Saha¹, R. Roy³, P. P. Shilpa³, A. Palanisamy¹, M. Ghosh¹, A. Biswas³,
S. Roy³, A. Pal¹, K. Sarkar¹

- (1) Biophysics and Structural Genomics Division, Saha Institute of Nuclear Physics, Kolkata, India.
- (2) Corresponding author.
- (3) Presidency University, Kolkata, India.

Effect of microgravity on terrestrial organisms may help to understand the life in space and low gravity planets, yet we poorly understand it at the molecular systems level. In this work we have established a systems biology pipeline by integrating analytical tools and machine learning algorithms and applied this pipeline on published gene expression datasets of bacteria and human cells in spaceflight and simulated microgravity conditions. We applied this pipeline on *Pseudomonas aeruginosa* and *Salmonella enterica* serovar Typhimurium in microgravity. We have identified alteration of a large number of new cellular and metabolic pathways. Metabolic pathways in microgravity were rarely reported before, whereas in this analysis metabolic pathways are prevalent. Among those new pathways several of them are overlapped irrespective of species and experiments. Genes, based on their expression pattern, are clustered. The network mapping of genes within a cluster indicates the plausible functional connections in microgravity. The newly identified pathways and networks showed its connection with increased survival of pathogens within macrophages, virulence and antibiotic resistance in microgravity.

On human cells, we have analyzed more than 8000 molecular pathways. Hundreds of new pathways for individual datasets have been identified. In spite of the differences in experimental conditions and cell types, around 100 new pathways are appeared common across the datasets. We have identified reduced inflammation, autoimmunity, diabetes and asthma, which are supported by multiple new pathways. Further downregulation of NfkB pathway via Notch1 signaling is identified as new pathway for reduced immunity in microgravity. Gene expression signatures related to induction of liver cancer and leukemia and increased drug response to cancer in microgravity are also found. Increase in olfactory signal transduction is also identified. This study gives a new and integrated molecular systems level understanding of human and bacterial cells under microgravity. The results may help designing new experiments in space biology and developing synthetic biology solutions for future space missions.

Effects of wind driven saltation on the survival of bacteria on Mars

E. N. Bak¹

M. Goul¹, R. Moeller², P. Nørnberg¹, S. K. Jensen³, K. Finster^{1,4}

- (1) Department of Bioscience, Aarhus University, Denmark.
- (2) Institute of Aerospace Medicine, German Aerospace Center, Cologne, Germany.
- (3) Department of Chemistry, Aarhus University, Denmark.
- (4) Stellar Astrophysics Center, Department of Physics and Astronomy, Aarhus University, Denmark.

The habitability of the Martian surface is challenged by the aridity of the environment and the high UV and ionizing radiation. Additionally, mobilization of surface particles by wind leads to abrasion and triboelectric charging with concomitant discharges, which can give rise to a production of hydrogen peroxide and hydroxyl radicals. We have investigated the stress induced by wind-driven saltation by exposing bacteria directly to simulated saltation with basalt particles in a Mars-like atmosphere as well as exposing bacteria to quartz and basalt particles already abraded by simulated saltation. The number of colony forming units of *Pseudomonas putida* and *Deinococcus radiodurans* was reduced by more than two orders of magnitude within 24 hours after exposure to abraded basalt kept anoxic. Abraded basalt secondarily exposed to ambient air as well as abraded quartz had a similar but lower effect. We propose that the reduced viability is caused by a production of reactive oxygen species and an increased production of hydroxyl radicals by Fenton-like reactions facilitated by reduced transition metals in the abraded basalt kept anoxic. Wild-type spores of *Bacillus subtilis* as well as mutant strains lacking different spore components were unaffected by the abraded material. However, the number of colony forming *B. subtilis* spores was reduced by two orders of magnitude after one hour of direct exposure to simulated saltation and by more than three orders of magnitude within 5 days. The low viability of vegetative cells exposed to abraded basalt and the fast inactivation of spores directly exposed to simulated saltation under Mars-like conditions indicate that the Martian surface may be more hostile than previously thought. This might limit the risk of forward contamination but may also pose additional challenges for indigenous organisms. The dramatic effects observed with usually highly resistant bacteria indicate that the reactivity of abraded basalt also could be a challenge for future manned missions. However, the reduced effects of basalt secondarily exposed to ambient air suggest that the health hazard associated with inhaling Martian dust would be limited in a human habitat.

Preservation of carotenoids in cyanobacteria and green algae after space exposure: a potential biosignature detectable by Raman instruments on Mars

M. Baqué¹

U. Böttger², T. Leya³, J-P. de Vera¹

- (1) German Aerospace Center (DLR), Institute of Planetary Research, Management and Infrastructure, Research Group Astrobiological Laboratories, Berlin, Germany.
- (2) German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin, Germany.
- (3) Fraunhofer Institute for Cell Therapy and Immunology, Potsdam-Golm Location (IZI-BB), Research Group Extremophile Research & Biobank CCCryo, Potsdam, Germany.

Forty years after the Viking missions, International space agencies are ready to resume the search for life on Mars (and in our Solar System). Indeed, new instruments are able to detect traces of extant or extinct life. They will be sent to Mars on-board the two next rovers: ExoMars2020 and Mars2020. Among them, instruments based on Raman spectroscopy are very promising thanks to their capacity to identify both the mineralogical context and organic molecules of potential biogenic origin. However, in order to support these future missions, it is very important to investigate the degree of preservation and the evolution of potential biosignatures under simulated and real space conditions by Raman spectroscopy. To this end, the BIOMEX (BIOlogy and Mars EXperiment) experiment aims at investigating the endurance of extremophiles and stability of biomolecules under space and Mars-like conditions in the presence of Martian mineral analogues (de Vera et al. 2012). BIOMEX was part of the EXPOSE-R2 mission of the European Space Agency which allowed a 15-month exposure, on the outer side of the International Space Station, which comprises also three other astrobiology experiments between July 2014 and February 2016. Among the potential biosignatures investigated, the photoprotective carotenoid pigments (present either in photosynthetic organisms such as plants, algae, cyanobacteria and in some bacteria and archaea) have been classified as high priority targets for biomolecule detection on Mars and therefore used as a model biosignature due to their stability and easy identification by Raman spectroscopy (Böttger et al. 2012). We report here on the first results from the analysis of two carotenoids containing organisms: the cyanobacterium *Nostoc* sp. (strain CCCryo 231-06; = UTEX EE21 and CCMEE 391) isolated from Antarctica and the green alga cf. *Sphaerocystis* sp. (strain CCCryo 101-99) isolated from Spitsbergen. Desiccated cells of these organisms were exposed to space conditions and to simulated Mars-like conditions in space. They were cultured on Martian mineral analogues (Phyllosilicatic and Sulfatic Mars Regolith Simulants) and a Lunar regolith analogue and analyzed with a 532nm Raman spectroscope operating at 1mW laser power. Carotenoids in both organisms were surprisingly still detectable at relatively high levels after being exposed for 15 months in Low Earth Orbit to UV, cosmic rays, vacuum (or Mars-like atmosphere) and temperatures stresses regardless of the mineral matrix used. Further analyses will help us to correlate these results with survival potential, cellular damages or stability and the different extremophiles tested in the BIOMEX experiment.

Survival of MASE strains under different aspects of simulated Martian conditions

K. Beblo-Vranesevic¹

M. Bohmeier¹, P. Rettberg¹, MASE-Team²

- (1) Institute for Aerospace Medicine, German Aerospace Center (DLR e.V.), Germany.
- (2) MASE-Team: Schwendner, P., Cockell, C.S. (Coordinator) (GB), Perras, A., Moissl-Eichinger, C. (AT), Gaboyer, F., Westall, F., Walter, N. (F), Garcia-Descalzo, L., Gomez, F., Malki, M., Amils, R. (ES), Monaghan, E., Ehrenfreund, P. (NL), Vannier, P., Marteinson, V. (IS).

During the project MASE (Mars Analogues for Space Exploration) several microbial isolates were obtained and some of these strains were subjected to Mars relevant environmental stress factors in the laboratory under controlled conditions; e.g. radiation, low water activity, high salt concentrations, oxidizing compounds. All sampling, isolation, and cultivation steps, as well as the stress tests were performed under anoxic conditions. So far, five only distantly related microorganisms are under detailed investigation: *Buttiauxella* sp. MASE-IM-7, *Clostridium* sp. MASE-IM-4, *Halanaerobium* sp. MASE-BB-1, *Trichococcus* sp. MASE-IM-5, and *Yersinia* sp. MASE-LG-1. It was shown that tolerance to desiccation and to ionizing radiation, applied separately was not correlated. If desiccation and exposure to radiation was applied together typical additive effects could be observed in each species. The survival after addition of oxidizing compounds (hydrogen peroxide; perchlorates) for a dedicated time (15 minutes; 24 hours) was very diverse. If the five microorganisms were compared with each other, *Trichococcus* sp. MASE-IM-5 was the most sensitive strain and survived only 10 mM hydrogen peroxide for 15 minutes and 24 hours, respectively. The most tolerant organism was *Halanaerobium* sp. MASE-BB-1 which was able to survive 100 mM hydrogen peroxide for both tested time points. In between, the other Bacteria were arranged with different tolerances against hydrogen peroxide. Comparable, species specific results were obtained after the addition of different perchlorates. In general, the strategy of the MASE project has proven to be useful to gain new model microorganisms. The isolated and characterized MASE strains have so far unknown high tolerances against cell damaging treatments and may serve as model organisms for future space exposure experiments.

Endurance of desert-cyanobacteria biofilms to space and simulated Mars conditions during the EXPOSE-R2 space mission

D. Billi¹

C. Verseux¹, E. Rabbow², P Rettberg²

- (1) Department of Biology ,University of Rome “Tor Vergata”, Department of Biology, Rome, Italy.
- (2) German Aerospace Center (DLR), Institute of Aerospace Medicine, Cologne, Germany.

The aim of the experiment Biofilm Organisms Surfing Space (BOSS), part of the EXPOSE-R2 space mission, is to test whether biofilms can withstand long-term exposure to space and Martian conditions than planktonic counterpart. Three desert isolates of *Chroococcidiopsis* spp. were included in the BOSS experiment: strain CCMEE 029 from endolithic communities in the Negev Desert, and strains CCMEE 057 and CCMEE 064 from endolithic and hypolithic communities in the Sinai Desert. Dried biofilms and dried multilayered planktonic samples were exposed to both ground-based simulations and to space and Martian simulated conditions in Low Earth Orbit (LEO) within the ESA facility EXPOSE-R2 outside the International Space Station. Samples were exposed for 16 months to space and Martian simulated conditions, characterized by temperature variations, ionizing radiation, vacuum or simulated Martian atmosphere, in the dark or under attenuated space and Mars-like and solar UV irradiation. The effects of those environments on cyanobacterial samples were investigated by using confocal laser scanning microscopy to visualize the biofilm architecture and quantify photosynthetic pigment autofluorescence, PCR-based assays to assess DNA damage and colony forming ability to test the recovery upon rehydration. Results from the flight mission are consistent with previous ground-based simulations of the mission^{1,2} and demonstrate an overall higher resistance of biofilms when compared to the planktonic counterpart, showing the former an increased viability and lower amounts of DNA damage.

References

- [1] Baqué M, Scalzi G, Rabbow E, Rettberg P, Billi, D. Biofilm and Planktonic Lifestyles Differently Support the Resistance of the Desert Cyanobacterium *Chroococcidiopsis* Under Space and Martian Simulations. *Orig. life Evol. Biosph.* 43, 377–389 (2013).
- [2] Baqué M, de Vera J.-P., Rettberg P, Billi, D. The BOSS and BIOMEX space experiments on the EXPOSE-R2 mission: Endurance of the desert cyanobacterium *Chroococcidiopsis* under simulated space vacuum, Martian atmosphere, UVC radiation and temperature extremes. *Acta Astronaut.* 91, 180–186 (2013).

Mars Analogues for space exploration – A summary of results

C. S. Cockell¹

- (1) UK Center for Astrobiology, School of Physics and Astronomy, University of Edinburgh, James Clerk Max-well Building, Peter Guthrie Tait Road, Edinburgh, EH9 3FD, UK, email: c.s.cockell@ed.ac.uk.

Astrobiology seeks to understand the limits of life and to determine the physiology of organisms in order to be able to better assess the potential habitability of other worlds and improve our ability to assay them for the presence of life. To successfully achieve this we require representative microorganisms from environments on Earth that in physical and/or chemical conditions approximate to extraterrestrial environments. The most challenging of these environments with respect to the sample collection and follow on isolation and cultivation of microorganisms are anaerobic environments. Here we describe a systematic approach to this challenge and aim to provide a guideline for future field work and sampling campaigns. We selected a number of anaerobic environments based on characteristics that make them analogous to past and present locations on Mars (Icelandic lakes, sulfidic springs, deep hypersaline environments, acidic iron-rich environments and permafrost). We implemented a culturing approach to enrich organisms from these environments under anaerobic conditions using a defined medium that would allow for all organisms to be grown under identical culturing conditions in future physiological comparisons. We then isolated anaerobic microorganisms, carried out a study of their basic physiology and deposited these organisms in the DSMZ (Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH) culture collection to make them available to astrobiologists and microbiologists. These organisms can then be used for a variety of astrobiology projects. In MASE, the selected organisms are being artificially fossilised and matured and the ensuing biosignatures studied in order to aid the search for in situ biosignatures on Mars and in samples returned from Mars. This project represents the first attempt to implement a coordinated effort from the selection of extraterrestrial analog sites through to the isolation and the characterisation of organisms and their deposition within a culture collection.

Survival of lichens on the ISS-II: ultrastructural and morphological changes of *Circinaria gyrosa* after space and Mars-like conditions

R. de la Torre Noetzel¹

B. Miller, A.Z.,Cubero², L. G. Sancho³, L. Jordão⁴, E. Rabbow⁵, J. Meessen⁶, J. P. de Vera⁷

- (1) INTA, National Institute for Aerospace Technology, Madrid, Spain.
- (2) IRNAS-CSIC, Instituto de Recursos Naturales y Agrobiología de Sevilla, Sevilla, Spain.
- (3) UCM, Univ. Complutense Madrid, Madrid, Spain.
- (4) INSA, Instituto Nacional Saúde Doutor Ricardo Jorge, Lisboa, Portugal.
- (5) DLR, German Aerospace Center, Cologne, Germany.
- (6) HHU, Heinrich-Heine University Düsseldorf, Germany.
- (7) DLR, German Aerospace Center, Management and Infrastructure, Astrobiological Laboratories, Berlin, Germany.

Lichens are extremophile organisms, they live in the most extreme conditions, colonizing areas with extreme temperatures, high aridity condition and high UV-radiation. Therefore they have been by far the most successful settlers of the Antarctic continent. Also in the laboratory they survive temperatures near the absolute zero and absolute dryness without difficulty. Lichen species have distinct likes and dislikes when it comes to the physico-chemical properties of the substrate while the group of lichens as a whole is pretty adaptable to various substrata (from rocks to glass). The main feature/aspect of their evolutionary/ecological success of this capacity is the close symbiotic relation between two organisms, a fungi and a cyanobacteria or an algae [1], allowing them to survive at real space [2] and at Mars conditions [3, 4, 5], such as that on the ISS. At the exposure platform EXPOSE-R2 on ISS (2014-2016), samples of the lichen species *Circinaria gyrosa* belonging to the BIOMEX experiment (Biology and Mars Experiment, ESA) [5], were exposed during 18 months to real space and to a Mars simulated environment to study Mars habitability and resistance to real space conditions. Also the identification of biomarkers was done to include them as reference for future space missions to Mars (Exo Mars). After the return of the mission at June 2016, the first preliminary analysis were performed, showing the metabolic activity a quick and complete recovery of the dark space control samples exposed to space vacuum and Mars-like atmosphere. In contrast, the samples directly exposed to space radiation showed slow recovery in reference to their observed original activity. Electron and fluorescence microscopy techniques also revealed that the viability of *C. gyrosa* exposed to space conditions decreased in comparison to those exposed to Mars-like environment. Moreover, differences were observed between samples positioned at level 1 and level 2. In general, TEM and FESEM observations showed that samples at level 2 (basal samples) were slightly affected in their morphology/ultrastructure by the exposure conditions. In contrast, cellular ultrastructure alterations were clearly evident for samples exposed to space radiation, which led to a shrinkage process. The cell walls were irregularly shaped and debris of the major organelles were visible. Now, the biomolecular changes of the DNA are in study by PCR and sequencing techniques. In contrast to these studies, the biogeochemical variations will be examined with spectroscopic analyses (Raman) to look for possible degradation of cell surfaces and pigments which were in contact with terrestrial rocks, and Martian analogue regolith. These experiments will contribute to answer questions on the habitability of Mars, on the likelihood of the Lithopanspermia HYPOTHESIS y [8] and will be of relevance for planetary protection issues.

Enhanced Microbial Survival in Brines at Subzero Temperatures

J. Heinz¹

J. Schirmack¹, A. Airo¹, D. Schulze-Makuch^{1,2}

- (1) Center of Astronomy and Astrophysics, Astrobiology Group, Technical University of Berlin, Berlin, Germany.
- (2) SETI Institute, Mountain View, CA, USA.

Environments, on Earth and beyond, require the presence of liquid water to be considered habitable for life as we know it. Many environments, e.g. on Mars or within the icy moons, never reach temperatures above the freezing point of water, rendering these localities as likely uninhabitable. However, the presence of salts can depress the freezing point substantially and therefor greatly expand the range of potential habitats in our Solar System. Hence, the question remains if microorganisms can survive and thrive in such subzero brines. We conducted experiments with the halo- and cryo-tolerant bacterial strain *Planococcus halocryophilus* isolated from the activelayer of permafrost in the Canadian High Arctic to test this hypothesis. Cells were preconditioned in liquid growth media (DMSZ #92) with 9 wt.% NaCl at 25°C for one week and stored one day before the start of the experiment at 4°C. 2 ml of this cell suspension were added to 8 ml of the following eutectic salt solutions at the respective temperatures : 21 wt.% NaCl (23°C; 4°C; -15°C), 31 wt.% CaCl₂ (23°C; -15°C; -45°C); 53 wt.% NaClO₄ (23°C; -15°C; -30°C); and 51 wt.% Ca(ClO₄)₂ (23°C; -15°C; -55°C). Survival rates of the microbes in the salt solutions were determined by counting colony forming units. The results show that lower temperatures are beneficial for the viability of microbes in highly concentrated salt solutions. For example, in the NaCl samples all cells died within 20 days at room temperature. However, there was no significant reduction of cell numbers observed at -15°C in the same time period. Similar results were observed in the CaCl₂ solutions. Here, all cells died within 15 min at room temperature, but 3.5% of cells survived at -45°C for at least 6 days. In the presence of ClO₄⁻, cells died markedly faster. This could be due to the oxidizing character of ClO₄⁻ ions or the lower water activity in these samples. In the case of NaClO₄ all cells died within one hour at room temperature and survived about 24 hours at -30°C. Probably due to the higher ClO₄⁻ concentration and the presence of bivalent ions in the Ca(ClO₄)₂ all microbes within those samples died in less than 30 min, even at -55°C. In a second experiment the effect of an increased salt concentration on the viability of cells during freeze/thaw cycles was investigated. We found that a salt concentration of 9 wt.% NaCl is beneficial for the viability of *P. halocryophilus* compared to a NaCl free cell suspension when both samples are frozen at -50°C. In the sample with no added NaCl cells survived approx. 70 freeze/thaw cycles, while microbes in the salty samples survived over 200 cycles. Our preliminary results suggest that the ability of organisms to survive in subzero brines increases the range of environments that are potentially habitable and therefore suitable for the search for extraterrestrial life.

500 μm cell-aggregate of *Deinococcus* spp. was sufficient to survive after one-year exposure on ISS orbit in Tanpopo mission.

Yuko Kawaguchi¹

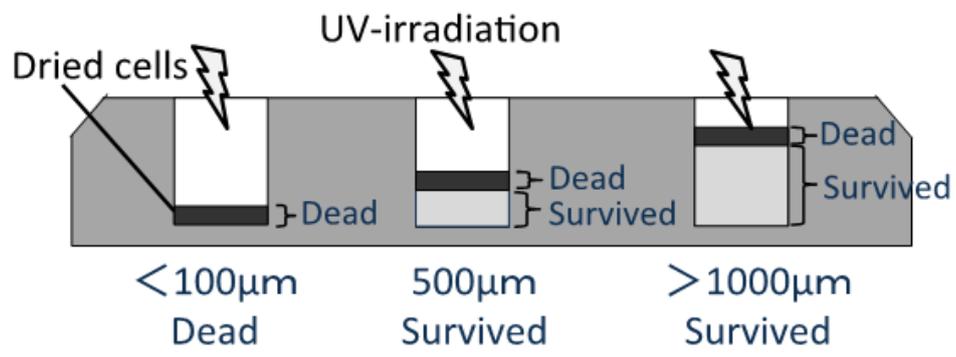
Iori Kinoshita¹, Jun Yatabe¹, Yuka Murano¹, Daisuke Fujiwara¹, Risako Hayashi¹, Miu Harada¹, Kazumichi Nakagawa², Issay Narumi³, Satoshi Kodaira⁴, Yukio Uchihori⁴, Hirofumi Hashimoto⁵, Shin-ichi Yokobori¹, Akihiko Yamagishi¹

- (1) School of Life Sciences, Tokyo University of Pharmacy and Life Sciences, Hachioji, Tokyo 192-0392, Japan.
- (2) Graduate School of Human Development and Environment, Kobe University, Kobe, Hyogo 657-8501, Japan.
- (3) Faculty of Life Sciences, Toyo University, Itakura, Gunma 374-0193, Japan.
- (4) National Institute of Radiological Sciences (NIRS), National Institutes for Quantum and Radiological Science and Technology (QST), Inage, Chiba 263-8555, Japan.
- (5) Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Sagami-hara, Kanagawa 252-5210, Japan.

Japanese astrobiology experiment Tanpopo is going on with investigation of panspermia hypothesis. Previous exposure experiments of microbes in space revealed that microbes inside of shieldings (e.g. small fragments of rock, mixture of sugar or clay) with sufficient thickness to protect from UV irradiation survived in space for a long period (e.g. Onofuri et al., 2012). On the other hand, we proposed interplanetary transfer of sub-millimeter cell-aggregates that survive under harsh space environment (Kawaguchi et al., 2013). The hypothesis was named massapanspermia. For the investigation of microbial survival and DNA damage induced in space, dried cells of the radioresistant bacteria *Deinococcus radiodurans*, *Deinococcus aereus*, *Deinococcus aetherius* and DNA repair-deficient mutants of *D. radiodurans* were put in wells of aluminum plates in Exposure Panels (EPs) and were exposed in space at the outside of Exposure Facility, Japanese Experimental Module of ISS since May 2015 (Yamagishi et al., 2007; Kawaguchi et al., 2016). After 384-day exposure, the first set of EPs were retrieved into the ISS pressurized area in June 2016, and returned to the ground laboratory in September 2016. Dried-deinococcal cell-aggregates with different thickness from single layer to about 1,500 μm were exposed in space. Dried-deinococcal cells with 100 μm -thickness irradiated with sunlight corresponding to $3.4 \times 10^3 \text{ kJ/m}^2$ (110–315 nm) UV dose were dead. Quantitative-PCR analysis revealed that intact DNA (%) in 100 μm -thickness sample was less than 1%. However, cell-aggregates with over 500 μm -thickness were alive. To investigate the DNA damage, we tested the survival of DNA repair-deficient mutants of *D. radiodurans*. Surviving fractions of the mutants exposed to space were lower than those of the ground control. We concluded that the cell-aggregates of 100 μm thickness were dead by UV-irradiation, however the 500 μm cell layer is sufficient to protect cells under surface from UV-radiation in space (Fig. 1). In addition, UV-induced pyrimidine dimers and ionizing radiation- and space vacuum-induced double-strand breaks were also detected in space exposed samples. In Tanpopo mission, cells were irradiated one direction. However, in space, particles of cells are irradiated from all directions. So the result suggests cell-aggregate in sub-millimeter as the ark for interplanetary transfer of microbes. The result strongly supports massapanspermia (Kawaguchi et al., 2013).

References

- [1] Arrhenius, 1908, *Worlds in the Making: the Evolution of the Universe*, Harper & Brothers.
- [2] Onofuri et al., 2012, *Astrobiology*, 12, 508–516.
- [3] Kawaguchi et al., 2016, *Astrobiology*, 16, 363–376.
- [4] Kawaguchi et al., 2013, *Orig. Life Evol. Biosph.*, 43, 411–428.
- [5] Yamagishi et al., 2007, *Bio. Sci. Space*, 21, 67–75.



Comparative resistance of subsurface *Tessarococcus* isolates from the Iberian Pyrite Belt to simulated Martian conditions

M. Malki¹

T. Leandro¹, R. Amils¹, Marteinsson V. Cockell C.S. (Coordinator), Beblo-Vranesevic K., Bohmeier M., Rettberg P., Schwendner P., Perras A., Moissl-Eichinger A.C., Gaboyer F., Westall F., Walter N., Garcia-Descalzo L., Gomez F., Monaghan E., Ehrenfreund P., Vannier P.²

- (1) Centro de Biología Molecular Severo Ochoa, Universidad Autónoma de Madrid, Spain.
- (2) MASE team.

During the development of the Mars Analogues for Space Exploration project (MASE) several microbial isolates of the *Tessarococcus* genus, a denitrifying actynomicetes, were obtained from enrichment cultures of samples from cores drilled at different depths in the Iberian Pyrite Belt. Some of these strains, isolates SSRT5 and SSRT8, were subjected to Mars environmental stress tests under controlled laboratory conditions; e.g. high salt concentrations, temperature, oxidizing compounds, radiation and low water activity. All sampling, isolation, and cultivation steps, as well as the stress tests were performed under strict anoxic conditions. The differences found between these isolates are remarkable. Isolate SSRT8 was able to grow efficiently at low temperature (4 °C). It was able to grow in the presence of 300 mM Ca, Mg and Na perchlorates and to resist up to 1M concentration of these salts. The sensitivity of isolate SSRT5 was dependent on the cation of the perchlorate. Isolate SSRT8 was more resistant to extended exposures to low temperatures (-80 °C) and exposure to 500Gy X-Ray radiation. Both isolates are extremely sensitive to freeze and thaw cycles, desiccation and starvation. Genomic comparison of both isolates is currently underway to detect the genetic basis of these important differences between two isolates from the same ecosystem.

Using a spinning satellite to determine the effect of gravity on ecosystem N-cycling

R. L. Mancinelli¹

J. Hauslage², P Richter³, S. Strauch³, M. Lebert³

- (1) BAER Institute, NASA Ames Research Center, Moffett Field, CA USA.
- (2) DLR Cologne, Germany.
- (3) Friedrich-Alexander-University, Erlangen, Germany.

Introduction: A goal of the DLR's Eu:CROPIS (Euglena Combined Regenerative Organic-food Production In Space) mission is to determine if gravity has an effect on the N-cycle in a simple ecosystem. Its core element is a microbiological trickling filter of lava rock – the habitat of a multitude of microbes that perform chemical transformation reactions important in ecosystem function, including the nitrogen cycle. Consequently, one objective of the project is to determine if gravity effects Eu:CROPIS's N-cycle. Nitrogen, an essential element for life is present in all living systems. Without nitrogen life as we know it could not exist. Because only Earth has a 1 x g environment understanding how the nitrogen cycle operates as a function of gravity is key to sustaining and understanding life off Earth. To change the gravity levels the spacecraft will be spun to produce two different gravity regimes for 6 months each during the mission. The two gravity regimes will be 0.16 x g (Moon gravity) and 0.38 x g (Mars gravity). It will be the first time nitrogen-transformation reactions will be measured as a function of gravity. Objectives: 1) Compare the rates of reactions of the N-cycle transformation reactions at each g level and in the ground control. 2) Develop a model of the N-cycle as a function of gravity. Hypothesis: The rates of N-transformation reactions change due to physiological effects of changes in the organisms performing these reactions and due to physical changes in the environment caused by gravity changes. Rationale: 1) Gene regulation changes occur in altered gravity. 2) Mixing due to convection decreases as gravity level decreases changing the concentration of N-species immediately surrounding the cell. Methods/Results: A ground control was constructed to mimic the flight system. Ion chromatography was used to measure the N species in the system. In the ground-control there is an initial increase in NH_4^+ (breakdown of urea) and a slow increase in NO_2^- (first step of nitrification), followed by a decrease in NO_2^- and a slow rise in the level of NO_3^- (second step of nitrification). There is a slow decrease in NO_3^- (denitrification). When the system is drained and a new batch of gray water is introduced, the production of NO_3^- occurs immediately. If the system is replenished every 10 days thereafter NO_3^- increases rapidly with little NO_2^- detected. One explanation is that the system is primed with all microbes at a higher population density in the trickling filter to readily begin metabolism, so as soon as NH_4^+ is produced it is transformed to NO_2^- that is immediately oxidized to NO_3^- . The rate of nitrification is faster if the pH is not controlled, but the total yield of NO_3^- is less, whereas if the system is buffered the rate of nitrification is slower, but the total amount of nitrate produced is greater. If the system is allowed to become anaerobic denitrification occurs and the system ceases to function properly.

First one year exposure results of organic compounds in Tanpopo mission

H. Mita¹

K. Kobayashi², Y. Kebukawa², K. Nakagawa³, K. Ishiyama³, R. Aoki², T. Harada², S. Misawa²,
E. Uchimura², T. Sato², K. Naito², S. Minematsu¹, E. Imai⁴, H. Yano⁵, H. Hashimoto⁵,
S. Yokobori⁶, A. Yamagishi⁶, R. T. Tanpopo⁶

- (1) Fukuoka Institute of Technology, Japan.
- (2) Yokohama National University, Japan.
- (3) Kobe University, Japan.
- (4) Nagaoka University of Technology, Japan.
- (5) JAXA/ISAS, Japan.
- (6) Tokyo University of Pharmacy and Life Sciences, Japan.

A Japanese astrobiological experiment called TANPOPO mission is performed on the Japanese Experiment Module of the International Space Station. In the TANPOPO mission, we are exposing organic compounds, especially amino acids and their precursors in space. Since amino acids are the most important and abundant organic compounds in living organisms, we mainly focus on amino acids. Although amino acids were found in many carbonaceous chondrites, lunar fines, and comet, those amino acids were detected after hydrolysis of the samples. Therefore, abundant compounds in the samples should be amino acid precursors, but not amino acids themselves. We choose the following five compounds for the space exposure: 1) glycine, 2) isovaline, 3) hydantoin, (a precursor of glycine), 4) 5-ethyl-5-methylhydantoin (a precursor of isovaline) and 5) products by proton irradiation of a gas mixture of CO, NH₃ and H₂O (hereafter abbreviated as CAW). CAW is a mixture of complex organic compounds including amino acid precursors. Last autumn, first one year exposed samples were returned to Earth. The analysis of remain of those compound were started to compare the stability of amino acids with those of their precursors in the space environment. Preliminary results and discussion will be shown in our poster.

The Biopause Project: Balloon Experiments for Sampling Stratospheric Bioaerosol

S. Ohno¹

K. Ishibashi¹, N. Miyake¹, O. Okudaira¹, Y. Kawaguchi², Y. Kakehashi³, M. Yamada¹, K. Yamada³, Y. Takahashi⁴, A. Yamagishi², T. Segawa⁵, S. Nonaka³, Y. Ishikawa⁶, G. Tokoro⁷, K. Yamanouchi⁸, M. Kobayashi¹, H. Fuke³, T. Yoshida³, T. Matsui¹

- (1) Planetary Exploration Research Center, Chiba Institute of Technology.
- (2) Tokyo University of Pharmacy and Life Sciences.
- (3) Japan Aerospace Exploration Agency.
- (4) Hokkaido University.
- (5) University of Yama-nashi.
- (6) University of Lincoln.
- (7) ISPA.
- (8) University of Tokyo.

Determining the location of the “biopause” (i.e., the upper boundary of the biosphere of the Earth) and the biological flux across the biopause are key to our understanding of the universality, distribution, origin, and evolution of life in the universe. It is widely accepted that the tropospheric atmosphere contains bioaerosol, although the flux of microbes from the troposphere to the stratosphere is small and dynamical and biological lifetime in the stratosphere are short. However, the presence of microbes in the stratosphere has been recorded in previous experiments using balloons, aircraft, and rockets. The most direct information available that can be used to investigate the biopause is the distribution and dynamicity of life in the middle atmosphere. The Biopause project used scientific balloons of the Japan Aerospace Exploration Agency (JAXA) to develop an overview of the stratospheric biosphere and the dynamics of biological flux in the stratosphere. The descending inertial impactor sampler was transported to the stratosphere using a balloon, where the balloon was released from the sampler. Sample collection was conducted as the sampler descended by parachute. This method reduces biological contamination dramatically as the particles that adhere to the balloon and the wall of the sampler cannot enter the sampler during the descent because the descent velocity of the particles (as determined by Stoke’s law) is less than the descent velocity of the sampler. Our first balloon experiment was conducted on June 8, 2016. The valves of the sampler were opened during its descent from an altitude of 27 to 13 km as planned. The recovered sample was analyzed using a fluorescence microscope and a scanning electron microscope (SEM). Using a fluorescence microscope, we identified 21 microbes on the impactor plate in the sampler. We also analyzed the collected aerosol particles using an SEM. In the presentation, we show the detailed results of the fluorescence microscope and SEM analysis. We estimated the number density of stratospheric microbes including those that cannot be cultivated. This is the first observational study of stratospheric bioaerosols to include nonculturable species and to successfully constrain their number density. Nonculturable microbes are thought to constitute the majority of stratospheric bioaerosols. These results from the first balloon experiment of the Biopause project represent an important step towards the planning of future experiments that will improve our understanding of stratospheric life and assist with the identification and characterization of the biopause. In this paper, we summarize the initial results of the balloon experiment and the initial results of sample analysis.

The BIOMEX space experiment: biosignatures detected after ground-based Science Verification Tests (SVT) in space and simulated Mars conditions

S. Onofri¹

C. Pacelli¹, L. Selbmann¹, L. Zucconi¹, R. Saladino¹, L. Botta¹, E. Rabbow², U. Boettger³,
J.-P. de Vera⁴

- (1) Department of Ecological and Biological Sciences (DEB), University of Tuscia, 01100 Viterbo, Italy.
- (2) German Aerospace Centre (DLR), Institute of Aerospace Medicine, 51170 Köln, Germany.
- (3) German Aerospace Center (DLR), Institute of Optical Sensor Systems, 12489 Berlin, Germany.
- (4) German Aerospace Center (DLR), Institute of Planetary Research, 12489 Berlin, Germany.

The BIOlogy and Mars Experiment (BIOMEX) is part of the European Space Agency (ESA) space mission EXPOSE-R2 in Low Earth Orbit (LEO), aiming to expose microorganisms for 1.5 years to space and simulated Mars-like conditions on the International Space Station (ISS). In preparation of this mission, dried colonies of the Antarctic cryptoendolithic black fungus *Cryomyces antarcticus* CCFEE 515, grown on Martian and Lunar analogue regolith pellets, were subjected to several ground-based preflight tests, Experiment Verification Tests (EVTs) and Science Verification Tests (SVTs). These tests aimed to verify i) the resistance of our model organism to space stressors when grown on extraterrestrial rock analogues and ii) the possibility to detect biomolecules as potential biosignatures in reference to support the Exomars 2020 mission. Here some results are reported showing the outcome of the SVTs, the last set of experiments, where the effect of UV radiation was analyzed if combined with simulated space vacuum or simulated Mars-like conditions. The analyses performed by Gas Chromatography-Mass Spectrometry showed the presence of fungal metabolites, as azelaic acid, that remain unaltered after the different expositions and treatments. In addition first results of Raman Spectroscopy analysis on melanin will be presented. Further investigation is necessary to derive the appropriate parameter set for Raman spectroscopy of melanin. Transmission Electron Microscopy (TEM) observations showed different results in preservation of cell's ultrastructure.

Tolerance of lichen-associated bacteria to astrobiological relevant conditions

A. Papadopoulos¹

R. Moeller², S. Ott¹

- (1) Institute of Botany, Symbiotic Interactions Research Group, Heinrich-Heine-University Dues-seldorf, Germany.
- (2) Institute of Aerospace Medicine, Radiation Biology, Space Microbiology Research Group, German Aerospace Center Cologne, Germany.

Lichens are symbiotic organisms, consisting of a heterotrophic mycobiont and a photoautotrophic photobiont. The symbiose is characterized by a mutualistic lifestyle. Lichens are colonizing all biomes worldwide. They are able to tolerate a wide range of extreme environmental conditions. Thus, some lichens are suitable model organisms in astrobiological viability studies. Within this frame, they participated in several real and simulated space exposure experiments and have shown a high resistance to non-terrestrial conditions. Recent research on lichen symbioses demonstrates that lichens are associated with manifold bacterial communities. These lichen-associated bacteria (LABs) have not been investigated in astrobiological research yet. The presented study demonstrates a tremendous viability of different lichen-associated bacterial species, which were isolated from *Xanthoria elegans*. They were studied by astrobiological relevant conditions, such as high dosage of ionizing and UV radiation. The viability was measured by a standard plate-assay using the counts of colony forming units (CFUs). The results indicated a remarkable potential of drought-tolerant lichen-associated bacteria to tolerate also high dosage of irradiation and possibly get use as novel putative model organisms in future astrobiological viability studies. The experiments were performed in Germany and Japan in collaboration of German Aerospace Institute in Cologne and Heinrich-Heine-University in Düsseldorf.

MEXEM – Mars Exposed Extremophile Mixture – a space experiment to investigate the capability of anaerobic organisms to survive on Mars

P. Rettberg¹

K. Beblo-Vranesevic¹, E. Rabbow¹, M. Bohmeier¹, S. Leuko¹, R. Moeller¹, T. Berger¹,
A. Antunes², C. Cockell³, L. Deng⁴, V. Marteinson⁵, T. Milojevic⁶, C. Moissl-Eichinger⁷,
B. Neilan⁸, C. Panitz⁹, P. Schwendner³, S. Stoeck¹⁰, M. Walter⁷, F. Westall¹¹

- (1) DLR, Institute of Aerospace Medicine, Koeln, D.
- (2) Edge Hill University, Ormskirk, UK.
- (3) University of Edinburgh, UK.
- (4) Helmholtz Zentrum Munich, D.
- (5) Matis ltd., Reykjavík, IS.
- (6) University of Vienna, AT.
- (7) Medical University Graz, AT.
- (8) Univ. New South Wales, Sydney, AU.
- (9) RWTH Aachen, D.
- (10) University of Kaiserslautern, D.
- (11) CNRS Orleans, F.

Assessing the habitability of Mars and detecting life, if it ever existed there, depends on knowledge of whether the combined environmental stresses experienced on Mars are compatible with life as we know it and whether a record of that life could ever be detected. So far, only few investigations were performed to understand the combined effect of different environmental stresses on survival and growth of anaerobic and extremophilic organisms. In the space experiment MEXEM (formerly known as MASE-in-SPACE) the hypothesis will be tested that selected terrestrial organisms, enrichment cultures and original samples from extreme Mars-analogue environments on Earth are able to withstand the Martian environmental stress factors due to their highly effective cellular and molecular adaptation and repair mechanisms. In addition, artificially fossilized and aged isolates from Mars-analogue environments on Earth will be examined and assessed with respect to their suitability for biosignature identification. MEXEM samples will be (i) oxygen-depleted natural sediment samples, (ii) natural sediments spiked with selected, defined strains representative for the respective analogue site, (iii) individual (facultative) anaerobic / micro-aerophilic species including ciliates and viruses, (iv) defined mixtures of these biological entities, (v) isolated strains from samples collected inside the ISS and (vi) artificially fossilized isolates from the natural environments. Most of these samples and isolates were obtained from Mars-analogue environments on Earth in the frame of the EC funded project MASE (Grant Agreement 607297) and from the space experiment EXTREMOPHILES (PI C. Moissl-Eichinger). MEXEM will be flown outside on the ISS in the new exobiology facility ESA is building now. It offers the possibility to simulate of the martian environment, in particular the martian UV climate, which cannot be done in the lab, but also martian atmosphere and pressure in LEO.

Metabolic response of *Yersinia intermedia* MASE-LG1 to osmotic stress

P. Schwendner¹

C. S. Cockell¹, A. Perras^{2,9}, P. Rettberg³, K. Beblo-Vranesevic³, M. Bohmeier³,
C. Moissl-Eichinger², V. Marteinson⁴, P. Vannier⁴, F. Gomez⁵, L. Garcia-Descalzo⁵,
P. Ehrenfreund⁶, E. P. Monaghan⁶, F. Westall⁷, F. Gaboyer⁷, R. Amils⁸, M. Malki⁸, P. Cabezas¹⁰,
N. Walter¹⁰

- (1) UK Centre for Astrobiology, School of Physics and Astronomy, James Clerk Maxwell Building, The King's Buildings, University of Edinburgh, Edinburgh, EH9 3FD, UK.
- (2) Medical University of Graz, Austria.
- (3) Deutsches Zentrum fuer Luft- und Raumfahrt e.V. (DLR), Germany.
- (4) Matis ohf., Iceland.
- (5) Centro de Astrobiología (INTA-CSIC), Spain.
- (6) Leiden Observatory, Leiden University, The Netherlands.
- (7) Centre National de La Recherche Scientifique (CNRS).
- (8) Centro de Biología Molecular Severo Ochoa (CSIC-UAM), Universidad Autonoma de Madrid, Cantoblanco, 28049 Madrid, Spain.
- (9) University of Regensburg, Department for Microbiology, Universitätsstr. 31, 93053 Regensburg, Germany.
- (10) European Science Foundation, France.

Osmotic stress is one of the major limitations for cell growth. Microorganisms can evolve adaptations to abiotic stresses like high salt concentrations in the environment. Sensor and signal transduction networks provide information to the cell about the osmolarity of its surroundings leading to an immediate metabolic response to counteract the osmotic stress. Some of these adaptations can be structural, some are metabolic. Our current knowledge of microbial responses to osmotic challenges is based on studies of representative bacteria, archaea, and eukaryotic microbes that is mainly focusing on the effect of NaCl. There is still a lack of understanding whether and how different salts, for example NaCl versus MgSO₄ alter the response of a microorganism to salt induced stress conditions. We chose *Yersinia intermedia* MASE-LG1 a strain isolated from an Icelandic lake as test organism. It is known for its abilities to adapt to a wide variety of habitats of rapidly changing environmental conditions. In order to identify which roles the different salts play in the global metabolic response, *Y. intermedia* was exposed sustained salt stress induced by either MgSO₄ or NaCl. After metabolite extraction, metabolic profiles from three replicate cultures of *Y. intermedia* MASE-LG-1 grown under 3 different conditions (e.g. control salt stressed in MgSO₄, and salt stressed in NaCl) were obtained. Generally, changes in numerous metabolites mainly in the amino acid metabolisms were observed in stressed samples compared to the control. To a lesser extent the carbohydrate metabolism was also affected. Looking at the effect of the different cations, the results clearly indicated significant differences in response to salt stress induced by the magnesium salt compared to sodium chloride. The results suggest that the amino acid synthesis, reflecting the general activity of translation operations, dominates the reaction to osmotic stress. These adaptations might provide necessary energy and building blocks to fuel processes conveying salt tolerance like the biosynthesis of compatible solutes. In addition we were able to identify metabolites which are linked to osmoprotective activity. The outcome of this study will have impact on our understanding of how microorganisms adapt to hostile environmental conditions.

Talks: Prebiotic chemistry and organics

4

Influence of hypomagnetic conditions on Earth's organisms in the context of different variants of panspermia theory.

W. Erdmann¹

Ł. Kaczmarek¹

(1) Department of Animal Taxonomy and Ecology, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University in Poznań, Poland.

Studies on the influence of magnetic field on Earth's organisms are important, not only in terms of knowledge of the history of life on Earth, but also in the context of contemporary astrobiology research. Many astrobiologists, consider the possibility of the spreading of different life forms in the space. Panspermia theory, concerns both: terrestrial organisms spreading to other celestial bodies, and life forms or its precursors reaching the Earth. But before that could be possible these life forms (terrestrial or extraterrestrial) have to survive long journey through the space. But the space is a hostile environment for all known living organisms due to high radiation, low pressure, extremely low temperature, and much more unfavourable factors. The lack of the geomagnetic field in space vacuum could have a great impact on the chances of potential living forms to survive the process of being spread through space. The geomagnetic field protects living organisms from space radiation and solar winds, but has also a significant influence on the metabolism of living organisms as was shown in numerous studies conducted both on plants and animals. For example, our own studies, on the influence of hypomagnetic conditions on mortality of tardigrade *Hypsibius dujardini*, has shown that the weakening of the geomagnetic field increases the mortality of this species, when it enters anhydrobiotic state or when it returns to active life. Based on the results of many studies which have been conducted since the turn of the fifties and sixties to the present day, we will consider what applications will take into account the hypomagnetic conditions for different variants of panspermia. Summarizing, we will try to answer the question: Does the reaction of the Earth's organisms to the lack of geomagnetic field determines if the panspermia phenomenon is possible or not?

References

- [1] Arrhenius S *Worlds in the Making: The Evolution of the Universe*. New York: Harper, brothers, 1908.
- [2] Blank M & Goodman R 1997 Do electromagnetic fields interact directly with DNA?. *Bioelectromagnetics*; 18(2), 111-115.
- [3] Dubrov AP. The geomagnetic field and life. *Geomagnetobiology*. Springer; 1978 edition (September 12, 2014), pp. 318.
- [4] Erdmann W Idzikowski B Kowalski W Szymański B Kosicki J.Z Kaczmarek Ł 2015 How tardigrades (water bears) respond to the Lack of the geomagnetic field. Conference materials, EANA 2015, Noordwijk 2015. pp. 34.
- [5] Kamminga H 1982 Life from space a history of panspermia. *Vistas in Astronomy*; 26, 67-86.
- [6] Lingam M 2016 Analytical approaches to modelling panspermia – beyond the mean-field paradigm. *Monthly Notices of the Royal Astronomical Society*; 455, 2792–2803.
- [7] Wesson P S 2010 Panspermia, Past and Present: Astrophysical and Biophysical Conditions for the Dissemination of Life in Space; *Space Science Review*; 156(1), 239–252 doi:10.1007/s11214-010-9671-x.

Space Travel: Challenges Ahead

S. Jheeta¹

(1) NoR HGT & LUCA.

The world population is expected to hit an all-time high of 14 billion within the next 50 years or so. With this in mind many eminent scientists (eg the former Royal Astronomer, Professor Lord Martin Rees) believe that man's destiny lies in travelling to planets such as Mars and further afield beyond our Solar System.

Is it a truth universally acknowledged, that man's future lies in the far-flung corners of the Universe? In this oral presentation, I will discuss the possibility of man-kind ever inhabiting the planet Mars or even becoming "space-farers" as depicted in films since the invention of moving pictures.

I will also address and assess Professor Stephen Hawking's recent notion of sending nano-robots to other star systems to search out life elsewhere in the Universe – is this a realistic possibility?

Towards a Generalized Theory of Living

T. P. Kee¹

(1) School of Chemistry, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK.

As chemists, when we look at biological life, we see chemicals, reactions between them, exchanges of energy from one part of system to another and between the system and environment. We see also, the intricate and regulated mechanistic interplay between large molecular ensembles (DNA, RNA, Ribosome) leading to the synthesis of new classes of large molecular assemblies (proteins), which subsequently have some functional value to the system itself. We ask how these molecules came to be, why these reactions and not others, how is the complex interconnectedness of the system built and regulated. These are most valid questions, yet the traditional prebiotic chemistry tool in trying to answer such questions is reductionist and such a method has a rather fine-grained optic. How might one adopt a more coarse-grained view of what life is? Is it possible to develop a generalized theory for life?

A focus on energy transduction is one that might prove valuable in helping formulate such as general model of living. Biological (cellular) systems are essentially complex chemical factories for the dissipation of energy from one form to another. They are, as Prigogine pointed out, examples of far-from-equilibrium arrangements whose thermodynamic properties conducive to building complexity through stochastic, spontaneous, self-organizing behavior. Prigogine called such arrangements, dissipative systems and they allow us to widen the optic of the systems view even further. Prigogine illustrates this himself by pointing out that dissipative systems are not solely the province of biology, but can be found all around us: rivers, volcanoes, civilizations, cities, weather patterns, our own planet, our solar system, galaxy clusters and our universe itself. All such structures share a common drive towards transducing energy, and using some of that energy to build complex arrangements through spontaneous self-organization of mutually interacting elements; molecules, fluid droplets. Cloud formations, sand or dust particles, banking systems, communications networks, stars and galaxies. In so doing, the system is better able to increase the overall entropy (or information, to which entropy is intimately connected mathematically) of the universe in compliance with the second law of thermodynamics. What differs between these different exemplars of dissipative arrangements is the mechanism by which they achieve the same overall goal.

In this presentation, I will discuss some features of a simple(simplistic?) generalized model for life which may, hopefully, help provide a framework for the search for life and a deeper understanding of how it may have emerged.

Is the Strecker Synthesis a Major Formation Pathway of Amino Acids in Space?

K. Kobayashi¹

T. Ito¹, S. Enomoto¹, Y. Kebukawa¹, H. Mita², Y. Muramatsu³, T. Ouch³, S. Hamanaka³,
H. Fukuda⁴, Y. Oguri⁴

- (1) Yokohama National University, Japan.
- (2) Fukuoka Institute of Technology, Japan.
- (3) University of Hyogo, Japan.
- (4) Tokyo Institute of Technology, Japan.

A wide variety of amino acids have been detected in water extract of carbonaceous chondrites, and amino acids have been abiotically synthesized in simulated extraterrestrial and terrestrial environments. Since the yields of amino acids were largely increased after acid-hydrolysis, major part of amino acids were present as their precursors either in meteorites or products of simulation experiments. Since Miller proposed the Strecker Synthesis was a possible mechanism of amino acid formation in his spark discharge experiment [1], it has been a priori assumed as a major formation pathway of amino acid formation in space. If so, aminonitriles should be found as a major amino acid precursor in extraterrestrial samples. On the other hand, hydantoins, another possible glycine precursor, was identified in carbonaceous chondrites [2]. We found that complex molecules were formed in experiments simulating extraterrestrial environments such as interstellar ices, and amino acids were formed after acid hydrolysis of the products [3], which suggested that there were amino acid precursors with large molecular weights. In the present study, we characterized amino acid precursors in the products by proton irradiation of simulated interstellar media, and in the products by spark discharges of simulated primitive atmosphere. Spark discharges (SD) were conducted in a gas mixture of CH₄, N₂ and H₂O by using a Tesla coil to simulate reactions in planetary atmosphere. A gas mixture of CO, NH₃ and H₂O was irradiated with 2.5 MeV protons from a Tandem accelerator (Tokyo Tech) (PI) to simulate reactions in interstellar media. The product of the latter is hereafter abbreviated to as CAW. Retention times of possible glycine precursors (aminoacetonitrile (AAN), glycinamide (GA) and hydantoin (Hyd)) by cation exchange HPLC or reversed-phase HPLC were determined, and then the products were fractionated into several fractions, including the fractions that could contain AAN, GA and/or Hyd. Amino acids in each fraction were determined by cation exchange HPLC after acid-hydrolysis. The upper limits of the ratios of (AAN + GA) to all the glycine precursors were 8% (SD) and 30% (PI), respectively, while those of Hyd were 17% (SD) and 6% (Hyd). FT-IR and XANES spectra of the PI product showed intense peaks corresponding to amide bonds, but we could not find peaks corresponding to nitriles in them. Thus we concluded that most of the glycine precursors in the products were not nitriles, amino acid amides nor hydantoins, but complex precursors having amide bonds. The present results strongly suggested that the Strecker synthesis is not a major amino acid formation pathway in space.

References

- [1] S. L. Miller and H. C. Urey, *Science*, 130, 245-251 (1959).
- [2] G. W. Cooper and J. R. Cronin, *Geochim. Cosmochim. Acta*, 59, 1003-1010 (1995).
- [3] Y. Takano et al., *Appl. Phys. Lett.*, 84, 1410-1412 (2004).

A Novel Wet–Dry Apparatus for Simulating Prebiotic Hydration–Dehydration Cycles under Strictly Anaerobic Atmospheres

H. L. Pleyer¹

S. Fox¹, H. Strasdeit¹

(1) Department of Bioinorganic Chemistry, Institute of Chemistry, University of Hohenheim, 70599 Stuttgart, Germany.

Because of their diverse geophysical and geochemical conditions, primordial volcanic islands—particularly, their coasts—could have played a prominent role in chemical evolution before the origin of life (Strasdeit 2010). Geothermal activity provided warm to hot environments in which various catalytically active mineral surfaces were available. Abiotically formed organic compounds could have accumulated and concentrated in rock pools, where dehydration–rehydration cycles could have occurred. The dehydration was driven by geothermal heating and the rehydration by tides (rock pools inside or near the tidal zone) or rainfall (rock pools above the splash zone). Such wet–dry cycles can favor condensation reactions, including the formation of oligomers (for example, peptides; see, e. g., Forsythe et al. 2015, Lahav et al. 1978). Most of the reported reactions that took place under wet–dry conditions were performed in air. Early Earth’s atmosphere, however, contained almost no free oxygen near the surface (Haqq-Misra et al. 2011). We therefore designed a special device that allows the simulation of prebiotic hydration–dehydration cycles under *anaerobic* conditions: the “wet–dry apparatus” (WDA). One of the main parts of the WDA is a computer-controlled PTFE magnetic valve. The duration of an individual cycle and the number of cycles can be freely chosen. Typically, a 99.999 % pure nitrogen atmosphere (containing 3 vol ppm oxygen) is used; if necessary, the residual oxygen can be removed by bubbling through alkaline pyrogallol solutions. Because of the modular design, the WDA can be adapted to different experimental needs. For example, various flasks can be attached and the temperature can be varied. Currently, five identical apparatuses are in operation, three more are planned. Three initial experiments were conducted to evaluate possible applications of the WDA: (i) Inspired by the work of Lahav et al. (1978), the influence of wet–dry cycles and three different clay minerals on the formation of glycine peptides was investigated under anaerobic conditions; (ii) The stability of the amphiphilic, air-sensitive compound linoleic acid during wet–dry cycles was examined in the presence or absence of olivine; (iii) To study if the handling of extremely oxygen-sensitive compounds is also possible, an alkaline pyrogallol solution was subjected to wet–dry cycles in the WDA. An overview of the experimental setup, the operating principle of the WDA, possible modifications, and the results of the test applications will be presented and discussed. References Forsythe et al. (2015) *Angew. Chem. Int. Ed.* 54, 9871–9875. Haqq-Misra et al. (2011) *Astrobiology* 11, 293–302. Lahav et al. (1978) *Science* 201, 67–69. Strasdeit (2010) *Palaeodiversity* 3(Supplement), 107–116; http://www.palaeodiversity.org/pdf/03Suppl/Supplement_Strasdeit.pdf.

Microbial mediation of minerals –terrestrial or parent body processes?

M. Polgári¹

I. Gyollai^{1,2}, Sz. Bérczi¹, M. Veres³, A. Gucsik³, E. Pál-Molnár⁴

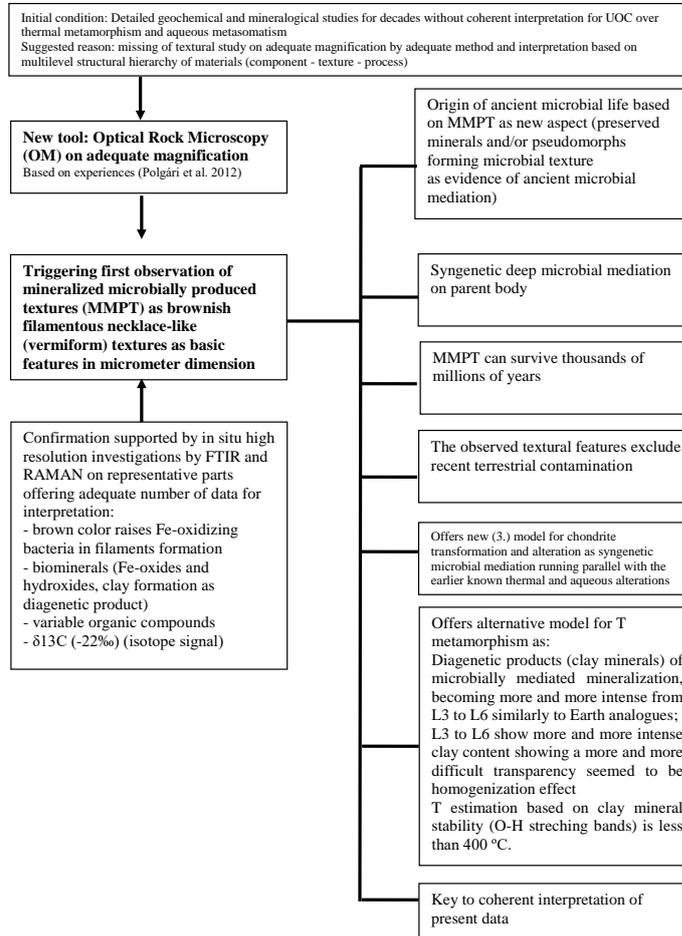
- (1) Eötvös University, Dept. of Materials Physics, Cosmic Materials Space Res. Group, H-1117 Budapest, Pázmány P. str. 1/a, Hungary, gyildi@gmail.com.
- (2) Research Center for Astronomy and Geosciences, IGG, HAS, 1112 Budapest, Budaörsi str. 45, Hungary, rodokrozit@gmail.com.
- (3) Wigner Research Centre for Physics, HAS, H-1121 Budapest, Konkoly-Thege M. sstr. 29-33, Hungary, veres.miklos@wigner.mta.hu.
- (4) University of Szeged, Dept. of Mineralogy, Geochemistry and Petrology, 'Vulcano' Petrology and Geochemistry Research Group. 6722 Szeged, Egyetem str. 2, Hungary, palm@geo.u-szeged.hu.

The evolution of chondritic parent body is influenced by thermal and impact metamorphism and aqueous alteration, which have been studied in Mező-Madaras, Knyahinya, Mócs and Nyírábrány in aspect of high resolution in situ textural, mineralogical and organic geochemical characteristics, using optical microscopy, FTIR-ATR and Raman spectroscopy. Our observations focused on the Fe-containing opaque grains, glass, olivines and pyroxenes, which were well populated by micrometer-sized microbial filamentous elements (clusters) in their boundary region within matrix and inside the minerals resembling mineralized microbially produced textures (MMPT), affecting 70-80% of the samples. In the MMPT iron oxides (ferrihydrite, goethite) [1], olivine [2], montmorillonite [3], various hydrocarbon compounds [4], and also kandite minerals [5] were identified. Interpretation 1: Data confirm dense and invasive terrestrial microbially mediated contamination in the chondrites, supported by microtexture, micromineralogy and embedded organic compounds, which affected most of the mass (80%) of the samples. As the transformation processes are supposed to happen on the parent bodies, it raises contradictions as it seems that these products manifest in microbially mediated texture [6]. Interpretation 2: Based on terrestrial analogies, microbial mediation is a sudden process comparing to geological times, very ancient, widespread and occur in various (extreme) environments under determined conditions. It can diminish and also produce minerals, if the chemical compounds (Fe, etc), wet conditions, Eh and pH are favourable [7]. After formation, MMPT can survive billions of years proposing occurrence on parent bodies (Fig. 1A-B) [8]. Our study (1) offers key to coherent interpretation of present data, (2) offers an alternative model for homogenization of chondrites by microbial weathering and subsequent diagenesis, (3) suggests that primitive microbial constituents also contributed to the formation of the early planetary accretion, and it offers new (3) model for chondrite transformation and alteration as syngenetic microbial mediation running parallel with thermal and aqueous alterations, (4) suggests that formation of life in the Solar System had began to develop from the microbial level, (5) raising that „microbially contaminated dust grains” (dormant microbes) can continuously streaming from presolar objects even today.

References

- [1] Glotch TD, Rossman GR (2009) *Icarus* 204:663–671.
- [2] Matrajt, G et al. (2005) *Astron & Astrophys* 433:979–995.
- [3] Parikh SJ, Chorover J (2006) *Langmuir*, 22:8492–8500.
- [4] Rajasekar, A et al. (2006) *Corros Sci* 47:257–271.
- [5] Frost RL (1995) *Clays & Clay Miner* 43/2:191–195.
- [6] Gyollai, I et al. 2017 #2005 Workshop Chondr. & Protoplanet. Disk.
- [7] Konhauser KO (Ed.) (2012) *Fundamentals of Geobiology*, Wiley–Blackwell Sci. Ltd., New York, 50–210.
- [8] Polgári M et al. (2012) *Geology* 40/10:903–906.

Figure 1 (A): Summary of hierarchy of the novel results and interpretations



Space Factor

Space Factor: Space Factor Contest

5

Abundance of radiation-resistant bacteria along an aridity gradient in the Atacama Desert – Are radiation- and desiccation resistance connected from the habitat perspective?

D. Boy^{1,4}

R. Godoy², L. Sauheitl³, G. Guggenberger³, J. Boy³, R. Moeller⁴

- (1) Leibniz Universität Hannover, Institute of Physical Geography and Landscape Sciences, Hanover, Germany.
- (2) Instituto de Ciencias Ambientales & Evolutivas, Universidad Austral de Chile, Valdivia, Chile.
- (3) Leibniz Universität Hannover, Institute of Soil Sciences, Hanover, Germany.
- (4) DLR, German Aerospace Center, Space Microbiology Research Group, Cologne, Germany.

Desiccation resistant bacteria are common model organisms for the search of life, as they survive even in the most hyper-arid regions (Navarro-Gonzalez et al. 2003). Resistance to desiccation is thought to be paired with a distinct resistance to ionizing radiation due to the same microbial DNA repair mechanisms (Mattimore et al. 1995). To test the hypothesis that the abundance of radiation resistant bacteria (RRB) increases with the aridity of their habitat, we sampled a humidity gradient (arid to hyper-arid) in the Atacama Desert, Chile, spanning roughly 600 km along the central Andean depression. All sampled sites had comparable inclination, altitude, and distance to the sea (50km). On each site three independent soil pits were sampled in the depth increments of 0-1, 5-10, 10-20, 30-40, and 50-60 cm and soil organic carbon (SOC, an indirect indication for the abundance of life) and soil water content (SW) were determined. Gamma radiated (up to 25.000 Gy) soil aliquots were taken into cultivation on a medium favoring the growth of Deinococcus-like species and colony numbers were counted thereafter. SOC stocks and SW content decreased significantly from 25.5 to 2.1 kg m⁻² cm⁻¹ and 60 to 1 mg g⁻¹ along the gradient, thus a severe decrease of biotic activity and moisture was observed. Surprisingly, the number of colonies of RRBs did not increase with aridity. Thus, a direct connection between aridity and radiation-resistance was not observed, although RRBs represented an increasing part of the bacterial community the drier habitat conditions became. Additionally, RRBs appeared in all soil depths along the gradient, including 60 cm soil depth. This indicates that radiation resistance is not limited to radiation-exposed habitats, pointing towards the hypothesized link of desiccation and radiation resistance. Our results show that radiation-resistant bacteria not only appear under hyper-arid conditions, but are also able to survive on sites with higher ecologic competition where both aridity and radiation play a comparably smaller role.

Hydrogels

A. V. Dass¹

T. Georgelin^{1,2}, T. P. Kee³, A. Brack¹, F. Westall¹

- (1) Centre de Biophysique Moléculaire (CBM), Rue Charles Sadron, 45071 Orléans, France.
- (2) Sorbonne Universités, UPMC Univ Paris 06 and CNRS UMR 7197, LRS case courrier 178, UPMC 4 Pl. Jussieu, 75252 PARIS CEDEX 05.
- (3) School of Chemistry, University of Leeds, Leeds, LS2 9JT, UK.

The commonality between gels and cells provides compelling grounds for exploring the relevance of gels in the origin of life. Herein, we draw parallels between the behavior of cytoplasm in contemporary cells and hydrogels. There is need for the exploration of hydrogels in particular, keeping in mind the geological relevance of inorganic species to origins of life[1]. One of the fundamental problems in prebiotic chemistry is the control of water activity in aqueous media (in peptide bond formation, phosphorylation, nucleotide polymerization), which is, thermodynamically, an uphill task. Our investigation into the importance of inorganic hydrogels began with study of D-ribose. D-ribose (C₅H₁₀O₅) is highly important because it is an integral part of DNA and RNA. The half-life of this molecule presents a considerable challenge in studying its role in origins of life. At pH 9 and 60°C, its half-life is about 50 h; in physiological conditions, at pH 7 and 37°C, it would be around 500 h if one extrapolates from the data of [2]. In solution, the D-ribose is in equilibrium with four isomers : α - and β -pyranose (β is the dominant isomer, 83%), and α - and β -furanose. Here, we present the homogenisation of ribose into hydrogel and the analysis of its diffusion properties in addition to its chemical and thermal stability. About 90% of the mobility of ribose is conserved in the hydrogel environment, which is similar to water, thus analogous to a cell environment. 1H NMR (DOSY sequence) was used for characterising the mobility of ribose in the gel. This environment also has effects on isomerization of D-ribose. We have not observed an evolution in the pyranose/furanose ratio, but have observed a progression of β -forms and a decrease of α -forms. In situ NMR and Raman spectroscopy have been used in order to evaluate the thermal behavior of ribose in the gel and in hydrothermal conditions on gels. Preliminary studies show a better thermal stability of the D-sugar in the gel. Hydrogels provide an environment and dynamics that are distinct from those in solution but nevertheless retain fluidity at a slower pace within a confined spatial arrangement. Such hydrogel matrices could also facilitate specific chemical interactions that appear to be necessary for prebiotic chemistry. Investigations on such properties are in progress [3].

References

- [1] Akouche et al. (2016) Chemistry- A European Journal 22, 44, 15834–46.
- [2] Larralde et al. (1992), PNAS 92(18), 8158-60.
- [3] Dass et al. (2016) Chemistry Select 1,15, 4906–26.

200 Candidates and Validated Planets from Year Two of K2

J. Livingston¹

M. Tamura¹, I. Crossfield², M. Werner³

- (1) University of Tokyo.
- (2) University of California, Santa Cruz.
- (3) Jet Propulsion Laboratory.

We report on planets discovered by the NASA K2 mission during its second year. We statistically validate a large fraction of these new candidate planetary systems based on our analysis of the K2 photometry, as well as intensive follow-up stellar spectroscopy and high resolution imaging, which also provide precise physical parameters for most systems. Of particular interest are planets with bright host stars amenable to characterization, multi-planet systems, and small planets receiving Earth-like irradiation. We show that K2 has significantly enhanced the number of promising targets for future atmospheric characterization, and we have performed follow-up transit photometry with Spitzer to help ensure the feasibility of such studies in the JWST era.

Time-resolved Raman spectroscopy for the detection of biomarkers in layered samples

B. J. A Mooij¹

G. R. Davies², J. F. de Boer¹, F. Ariese¹

(1) LaserLaB, Vrije Universiteit Amsterdam (Amsterdam, the Netherlands).

(2) Deep Earth & Planetary Science, Vrije Universiteit Amsterdam (Amsterdam, the Netherlands).

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

This report focuses on assessing the next generation space instrumentation for life detection below the Martian surface, using Raman spectroscopy. We currently focus on the detection of carotenoids, a widely accepted proxy for biosignatures[2].

Due to the high radiation levels on Mars, it is expected that any life would reside beneath the surface. Hence various bacteria were measured through several millimetre thick mineral by means of time-resolved Raman spectroscopy (TRRS). In a TRRS experiment, a pulsed laser and gated detection system is used to suppress the strong, unwanted Raman signals from the surface and selectively detect the much weaker Raman signals that originate deeper inside the sample and reach the detector later in time. Additionally, to obtain a further increase in specificity and also signal-to-noise ratio, the excitation wavelength is optimised for resonance Raman spectroscopy (RRS). Our previous research established that it is possible to detect the Raman signal of *D. radiodurans* through a 5-millimetre thick translucent mineral layer by applying an extra 100 picosecond delay in TRRS [3]. The next challenge is to also distinguish weaker and closer-lying multiple layers by analysing our signal more extensively. When different sample layers are less than about 3 millimetres thick, our TRRS set-up would not allow for a direct distinction since the time difference becomes much smaller than the detector gating time (typically 200-250 ps). However, by applying global data analysis methods (as described in [4]) to our TRRS data, we can distinguish thin layers down to even smaller temporal differences of 10-20 ps.

Our end goals are to optimise our set-up for the detection of biomarkers in a mineral environment and to develop future methods that increase the capability to detect possible life on Mars.

References

- [1] D. Slade and M. Radman (2011), *Microbiol. Mol. Biol. Rev.* vol. 75, no. 1, pp. 133–191.
- [2] J. Jehlička and H. G. M. Edwards (2014), *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.*, vol. 372, no. 2030.
- [3] M. F. C. Verkaaik et al. (2015), *Astrobiology*, vol. 15, no. 8, pp. 697–707.
- [4] I. H. M. van Stokkum et al. (2004), *Biochim. Biophys. Acta - Bioenerg.*, vol. 1657, no 2-3, pp. 82-104.

The Irradiation of Pure Methanol (CH₃OH) Ices at 30 K using 1 keV Electrons

M. Musariri¹

S. Jheeta¹, P. C. Simpemba²

- (1) The Copperbelt University, School of Mathematics and Natural Sciences, Department of Physics. P.O. Box 21692, Kitwe, Zambia.
- (2) Southern African Regional Office of Astronomy for Development, The Copperbelt University, P.O. Box 21692, Kitwe, Zambia.

The results of an experimental investigation of 1 keV electron irradiation of ice (at 30 K) of pure methanol, made under ultrahigh vacuum conditions (10^{-9} mbar), are reported here. Molecular products formed within the ice were detected and monitored using FTIR spectroscopy. The products made were methane (CH₄), formaldehyde (H₂CO), carbon monoxide (CO) and carbon dioxide (CO₂). The consequences of these results for prebiotic chemistry in the interstellar medium and star forming regions are discussed.

Dry riverbed in the Atacama desert: a depth profile analysis for biosignatures

P. Nauny¹

K. Simutis², J. Nainys², L. Mažutis², M. R. Lee¹, J. L. Toney¹, V. R. Phoenix^{1,3}

- (1) School of Geographical and Earth Sciences, University of Glasgow, Glasgow, UK.
- (2) Institute of Biotechnology, Vilnius University, Vilnius, Lithuania.
- (3) School of Engineering, Strathclyde University, Glasgow, UK.

The Atacama desert is one of the best planetary analogue sites, its extreme dryness makes it an excellent environment to test the limits of microbial life. Yet, some parts of this desert may still experience rain, thus draining surface molecules down and providing water to potential underground microcosms. What could be the nature of these molecules and microorganisms, and in the subsurface would they be found?

To answer these questions, soil samples were collected at 2 cm intervals, down to 21 cm below the surface in the bed of a former river, and the temperature and relative humidity were monitored underground for approximately 48 hours. DNA and lipids were extracted from the samples. Their mineralogy and sedimentology were also analysed.

The soil samples were sands, mainly composed of quartz, calcite, and albite. Lipids were found mainly at the surface and above a clay layer located approximately 15 cm deep. Most of the lipids found are likely to have a plant origin. DNA material is almost absent, and mostly fragmented at the surface levels. However, it was possible to amplify bacterial 16S rDNA in the surface samples, and both above and below the clay layer.

Samples are now being prepared for sequencing. A virtually unbiased single-DNA molecule amplification was performed by combining multiple displacement amplification and droplet microfluidics. Early metagenomic results will be presented along with geology and geoorganic chemistry data.

Survival of halophilic archaeon *Halovarius luteus* gen. nov., sp. nov., to desiccation, simulated Martian UV radiation and vacuum in comparison to *Bacillus atrophaeus*

F. Niloofar^{1,6}

S. Farid², H. T. Saeed³, N. Kamran⁴, M. Euan⁵, J. W. A. van Loon^{6,7}

- (1) Department of Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran.
- (2) Assistant Professor of Biophysics, MIM Daroo Pharmaceutical Co., Tehran, Iran.
- (3) Department of Biology, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
- (4) ACTA-Vrije Universiteit, Department of Oral Biochemistry, Gustav Mahlerlaan 3004 1081 LA Amsterdam, The Netherlands.
- (5) Huygens Laboratory, Leiden University, J.H. Oort Building, Niels Bohrweg 2, NL-2333 CA Leiden, The Netherlands.
- (6) DESC (Dutch Experiment Support Center), Dept. Oral and Maxillofacial Surgery / Oral Pathology, VU University Medical Center & Academic Centre for Dentistry Amsterdam (ACTA), Gustav Mahlerlaan 3004, 1081 LA Amsterdam, The Netherlands.
- (7) ESA-ESTEC, TEC-MMG, Keplerlaan 1, NL-2200 AG, Noordwijk, The Netherlands.

Some of the most ancient inhabitants on Earth are microorganisms with the capability of coping with high levels of salinity, even ten-fold that of sea water, also able to withstand high temperatures, extreme desiccation and ionizing radiation. Extraterrestrial environments have lethal effects on organisms and imply devastating tensions on their biochemistry due to high levels of radiation, extreme vacuum and temperatures, and lack of water and nutrients. Haloarchaea are considered interesting species for astrobiological studies due to high capabilities of tolerating desiccation, radiation and hypersaline environments. In this study a novel haloarchaea, isolated from Urmia Salt Lake, Iran, *Halovarius luteus* strain DA50T, was exposed to varying levels of simulated space conditions and compared with *Bacillus atrophaeus*. These conditions were: UV radiation, high and low vacuum and desiccation. Thin films were produced with different concentrations from both strains and their viability studied without any protective effect of thick cell multi-layers. *Hvr. luteus* and *B. atrophaeus* were desiccated in salt crystals and PBS, respectively. The simulated Mars UV light intensity was adjusted to 54.78 W/m² scaled to the distance of the sample from the lamp, to make a radiation environment similar to Mars conditions. Samples were exposed to desiccation and low and high vacuum conditions and their viabilities were studied by Most Probable Number methods for both strains. The proteome was analyzed by electrophoresis (SDS-PAGE). Changes in viability of the spore forming bacteria *B. atrophaeus* were only minor. On the other hand, the halophile strain under the extreme conditions demonstrated a range of different viabilities. The highest intensity radiation flux was 100 kJ/ m² with nitrogen gas and two weeks of desiccation shows the highest decrease in viability. This study further expands our understanding of the boundary conditions of astrobiologically relevant cells to survive the harsh environment of Mars-relevant conditions.

Key words: *Halovarius luteus*, *Bacillus atrophaeus*, desiccation, simulated Martian UV radiation, vacuum, Most Probable Number

Investigating the transfer and survivability of microbial cells within the stratosphere

T. Omairi¹

M. Wainwright¹

(1) Department of Molecular Biology and Biotechnology, University of Sheffield, UK.

Emerging evidence from numerous studies show that despite extreme conditions of the stratospheric layer of Earth, numerous microbes possess the ability to survive and replicate, previous studies also attempted to isolate microbes from the stratosphere with various levels of success. In this study, six stratospheric balloon launches were carried out over a three-year period from several sites around the globe, in order to sample the stratosphere for microbial cells and analyse the findings using imaging and molecular techniques, without overreliance on routine culturing protocols. Analysis of isolates was achieved using Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Spectroscopy (EDAX), and Molecular techniques, including Single-cell amplification. Results from SEM and EDAX enabled identification of numerous biological cells, in addition to determining the mechanism which was used to bring the cells to the stratosphere based on the sizes of the recovered cells using theoretical models from previous studies. Single-cell amplification and next-generation sequencing identification also showed the presence of DNA and revealed a diverse range of known microorganism, with many previously only isolated from deep hydrothermal vents and other extreme environments, therefore raising the question of the stratospheric environment's role in the evolution of microbial life, and its relevance as an analogous to the Martian surface environment. Results also demonstrate the value of the Single-cell amplification technique in analysing limited astrobiological samples while minimising contamination risks.

Autotrophy and biomineralisation of nitrate-dependent iron oxidisers on Mars-relevant mineral substrate

A. B. Price¹

V. K. Pearson¹, S. P. Schwenzer¹, K. Olsson-Francis¹

(1) Faculty of Science, Technology, Engineering and Mathematics, The Open University, Walton Hall, Milton Keynes, Buckinghamshire, UK.

Mars has abundant chemical energy available for microbial metabolism in the form of Fe²⁺-bearing minerals, such as olivine [1]. Mars is likely to have been anoxic throughout most of its history [2-4], largely precluding the development of oxygen as an oxidant in metabolism. Alternative oxidants, nitrates, have recently been detected at the modern martian surface and may have also been present in earlier periods of Mars' history [5, 6], when long-lived circumneutral aqueous environments existed and may have offered habitable conditions for life [7]. Similar modern environments on Earth are populated by nitrate-dependent Fe²⁺-oxidising (NDFO) microbes, which use Fe²⁺ and nitrates as electron donors and acceptors in anoxic conditions to provide energy for growth [8]. This crossover led us to investigate NDFO as a model for hypothetical early martian life.

The ability of four NDFO microbes to grow autotrophically on a solid Mars-relevant mineral Fe²⁺ source was tested experimentally in anaerobic batch-culture. Two strains, *Pseudogulbenkiania* sp. strain 2002 and *Acidovorax* sp. strain BoFeN1, were able to grow with a solid olivine substrate, whereas *Paracoccus* sp. strain KS1 and *Thiobacillus denitrificans* were not. However, live *T. denitrificans* cells were observed throughout the course of the experiment, implying that this species may be able to maintain cell viability under these conditions without exhibiting growth.

When grown in high (10 mM) dissolved Fe²⁺-media, *Acidovorax* sp. strain BoFeN1 was found to produce membrane-associated minerals as a by-product of NDFO. Energy-dispersive X-ray analysis identified the encrustation as primarily composed of iron and phosphorus. Further analyses of mineral products from all four cultured species will be presented.

The ability of some NDFO species to grow autotrophically on olivine supports the hypothetical viability of these microbes in the context of early Mars. Additionally, mineral encrustation of NDFO microbes may offer a mechanism for preservation of microbial morphologies, which could act as biosignatures in the rock record. To test these hypotheses, further work will invoke more accurate Mars conditions (e.g. salinity, variable ionic compositions) and investigate associated biomineralisation across a range of NDFO organisms.

References

- [1] McSween, H.Y., G.J. Taylor, and M.B. Wyatt, (2009), *Science*, 324(5928): 736-739.
- [2] Mahaffy, P.R., et al., (2013), *Science*, 341(6143): 263-266.
- [3] Sholes, S.F., et al., (2017), *Icarus*, 290: 46-62.
- [4] Jakosky, B., et al., (2017), *Science*, 355(6332): 1408-1410.
- [5] Manning, C.V., K.J. Zahnle, and C.P. McKay, (2009), *Icarus*, 199(2): 273-285.
- [6] Stern, J.C., et al., (2015), *PNAS*, 112(14): 4245-4250.
- [7] Grotzinger, J.P., et al., (2014), *Science*, 343(6169): 1242777.
- [8] Weber, K.A., L.A. Achenbach, and J.D. Coates, (2006), *Nat. Rev. Microbiol.*, 4(10): 752-764.

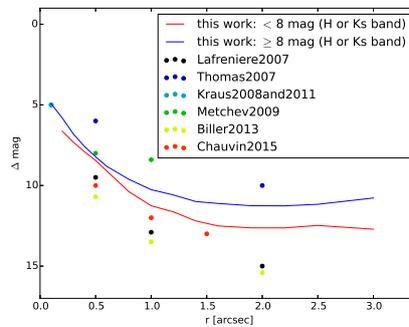
Search for Exoplanet around Young Stellar Objects

Uyama Taichi¹

Hashimoto Jun², Kuzuhara Masayuki², Tamura Motohide^{1,2,3}, D. Brandt Timothy⁴,
Tanigawa Takayuki⁵, Aoyama Yuhiko⁶

- (1) Department of Astronomy, The University of Tokyo.
- (2) Astrobiology Center of NINS.
- (3) National Astronomical Observatory of Japan.
- (4) Astrophysics Department, Institute for Advanced Study.
- (5) National Institute of Technology, Ichinoseki College.
- (6) Department of Earth and Planetary Science, The University of Tokyo.

We present near-infrared direct imaging observations for exoplanets around young stellar objects (YSOs) in two ways. Our scientific goal is to detect very young exoplanets and to discuss planet formation and disk-planet interactions. The first work is direct imaging survey as a part of SEEDS project with Subaru/HiCIAO. We observed 68 YSOs and achieved a typical contrast of $\sim 10^{-4}$ – $10^{-5.5}$ at an angular distance of $1''$ from the central star, corresponding to typical mass sensitivities (assuming hot-start evolutionary models) of $\sim 10 M_J$ at 70 AU and $\sim 6 M_J$ at 140 AU. The attached figure compares typical detection limits of our work and previous direct imaging surveys. We detected a new stellar companion to HIP 79462 and confirmed the substellar objects GQ Lup b and ROXs 42B b. An additional six companion candidates await follow-up observations to check for common proper motion. Our SEEDS YSO observations probe the population of planets and brown dwarfs at the very youngest ages; these may be compared to the results of surveys targeting somewhat older stars. Our sample and the associated observational results will help enable detailed statistical analyses of giant planet formation. The second work is direct imaging search for accretion signatures onto possible protoplanets within protoplanetary disks. Pa β line ($1.282 \mu\text{m}$) is an indication of accretion onto a protoplanet, and its intensity is much higher than that of blackbody radiation from the protoplanet. We focused on the Pa β line and observed TW Hya, which has a multi-ring disk exhibiting evidence of planet formation, with Keck/OSIRIS. Although no accretion signatures were detected using spectral differential imaging data reduction, the results of the present study allowed us to set 5σ detection limits for Pa β emission of 5.8×10^{-18} and 1.5×10^{-18} erg/s/cm² at $0.4''$ and $1.6''$, respectively. We considered the mass of potential planets using theoretical simulations of circumplanetary disks and hydrogen emission. The resulting masses were $1.45 \pm 0.04 M_J$ and $2.29^{+0.03}_{-0.04} M_J$ at 25 and 95 AU, respectively, which agree with the detection limits obtained from previous broadband imaging. The detection limits should allow the identification of protoplanets as small as $\sim 1 M_J$, which may assist in direct imaging searches around faint YSOs for which extreme adaptive optics instruments are unavailable.



Cyanobacteria as a substrate for heterotrophs – Implications for biological life-support systems on Mars.

C. Verseux¹

L. J. Rothschild², D. Billi¹

(1) Department of Biology, University of Rome Tor Vergata, Italy.

(2) Earth Science Division, NASA Ames Research Center, USA.

One of NASA's goals is to send humans to Mars in the early 2030s [1]. More generally, setting foot on the Red Planet is the most ambitious objective of space agencies in the foreseeable future.

While first missions will likely be short-term, a permanently inhabited outpost, akin to polar stations, will be desirable to perform extensive research activity on site. Unfortunately, sustaining an outpost on Mars by providing all life-support consumables from Earth is unrealistic. If humans are to spend considerable amounts of time on Mars, they will need to learn how to live "off the land" there.

A solution could be to rely on biological systems. Microorganisms, for instance, could be used for the production of drugs, food, oxygen, biomaterials and various industrially useful chemicals, for metal leaching and for waste processing [2]–[4]. However, if biological systems rely exclusively on materials imported from Earth, their running time without re-supply is limited. To be sustainable, such systems should be fed with resources found on Mars.

In 2011, the Brown-Stanford iGEM team, led by Dr. Lynn Rothschild, engineered a cyanobacterium to secrete sucrose. They suggested that this microbe could be the metabolic power centre for biotechnologies beyond Earth [3]. The concept was dubbed PowerCell.

In the following years, we consolidated the idea that a wide range of biological processes could be supported by specific cyanobacteria grown on Mars from local resources, either by secreting substrates or after cell disruption [3], [5]. To address the potential effects of altered gravity on the system, a PowerCell payload will fly on the DLR EuCROPIS satellite scheduled for launch in 2018.

Here, we report on a study aimed at testing Mars-relevant cyanobacteria as a source of nutrients for heterotrophic bacteria. Our results represent a step forward in the development of Earth-independent life support systems for Mars exploration.

References

- [1] 115th Congress of the USA, "National Aeronautics and Space Administration Transition Authorization Act of 2017," 2017.
- [2] C. Verseux, I. Paulino-Lima, M. Baqué, D. Billi, and L. Rothschild, "Synthetic Biology for Space Exploration: Promises and Societal Implications," in *Ambivalences of Creating Life. Societal and Philosophical Dimensions of Synthetic Biology*, K. Hagen, M. Engelhard, and G. Toepfer, Eds. Springer-Verlag, 2016, pp. 73–100.
- [3] L. J. Rothschild, "Synthetic biology meets bioprinting: enabling technologies for humans on Mars (and Earth)," *Biochem. Soc. Trans.* 44:1158–1164, 2016.
- [4] A. A. Menezes, J. Cumbers, J. A. Hogan, and A. P. Arkin, "Towards synthetic biological approaches to resource utilization on space missions.," *J. R. Soc.* 12:20140715, 2014.
- [5] C. Verseux, M. Baqué, K. Lehto, J.-P. P. de Vera, L. J. Rothschild, and D. Billi, "Sustainable life support on Mars – the potential roles of cyanobacteria," *Int. J. Astrobiol.* 15:65–92, 2016.

Posters

Characterising ultra-cool dwarfs on the search for exoplanets: the SPECULOOS project and the TRAPPIST-1 system

Michaël GILLON¹

Emmanuël JEHIN¹, Valérie VAN GROOTEL¹, Artem BURDANOV¹, Catarina FERNANDES¹,
Sandrine SOHY¹, Didier QUELOZ², Samantha THOMPSON², Amaury TRIAUD²,
Laetitia DELREZ², Sai LEIK², Brice-Olivier DEMORY³, Yasseen ALMLEAKY⁴,
Adam BURGASSER⁵, Julien de WIT⁶

- (1) Space Sciences, Technologies and Astrophysics Research (STAR) Institute, Université de Liège, Belgium.
- (2) Cambridge Exoplanet Research Center, University of Cambridge, UK.
- (3) Center for Space and Habitability, University of Bern, Switzerland.
- (4) Space and Astronomy Department, King Abdulaziz University, Saudi Arabia.
- (5) Center for Astrophysics and Space Science, University of California, USA.
- (6) Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, USA.

The SPECULOOS project will be Searching for habitable Planets Eclipsing ULtra-cOOl Stars, and will soon start looking at ultra-cool stars in our galaxy with four 1m robotic telescopes located at the ESO Paranal Observatory (Chile). The main goal is to find transiting Earth-sized planets in the habitable zone and provide potential targets for the Extremely Large Telescopes and the James Webb Space Telescope which can do atmosphere studies and search for biomarkers. A prototype program for the SPECULOOS project was carried out on the TRAPPIST telescope, by targeting the brightest ultra-cool dwarfs of the Southern hemisphere to search for transiting planets. This TRAPPIST program has led to the recent discovery of seven terrestrial planets orbiting a M8 dwarf at approximately 11 parsecs from Earth, known as the TRAPPIST-1 system (Gillon et al. 2017). We present this discovery and its newest results from the Kepler-2 mission where a long-cadence analysis confirmed the period of Trappist-1h (18.77 days), thus all seven planets being in orbital-resonance (Luger et al. 2017). In Luger et al. 2017, we find that the star shows flares consistent with a low-activity, middle-aged, late M dwarf. What are the implications of such a host-star to the habitability of the system? Studying and characterising the host-star is extremely important in the field of exoplanet research as it sets the constraints for the potential to sparkle life. At the University of Liège, we have recently adapted our in-house stellar evolutionary code CLES (Scuflaire et al. 2008) to precisely account for these kind of stars. With such improvement, we are able to set new constraints on the mass of Trappist-1 that could account for a middle-aged, ultra-cool dwarf star.

Microbially mediated siderite as candidate for possible carbonate impact ejecta

I. Gyollai^{1,2}

M. Polgári², Sz. Bérczi¹, M. Veres³, A. Gucsik³, E. Pál-Molnár⁴

- (1) Eötvös University, Dept. of Materials Physics, Cosmic Materials Space Res. Group, H-1117 Budapest, Pázmány P. str. 1/a, Hungary, e-mail: gyildi@gmail.com.
- (2) Research Center for Astronomy and Geosciences, Geobiomineralization and Astrobiological Research Group, Institute for Geology and Geochemistry, Hungarian Academy of Sciences, 1112 Budapest, Budaörsi út. 45, Hungary, e-mail: rodokrozit@gmail.com.
- (3) Wigner Research Centre for Physics, HAS, H-1121 Budapest, Konkoly-Thege M. str. 29-33, Hungary, e-mail: veres.miklos@wigner.mta.hu.
- (4) University of Szeged, Dept. of Mineralogy, Geochemistry and Petrology, 'Vulcano' Petrology and Geochemistry Research Group. 6722 Szeged, Egyetem str. 2, Hungary, palm@geo.u-szeged.hu.

Siderite (FeCO₃) concretions of different localities were studied to determine their mineralogical-geochemical features, using optical microscopy, FTIR-ATR, Raman spectroscopy, and IRMS. The purpose of study was the identification of origin of concretions and their exposed surface, and comparison with ejecta material of the same mineralogy. To recognize terrestrial originated "meteorites" on the surface, siderite looks to be the best candidate. It suffers degassing of the exposed surface on heat effect, and its color asks for macroscopic attention (shiny brown appearance) [1]. Based on data filamentous microtexture resembling putative microbial activity raised two step microbially mediated formation (suboxic, neutrophylic autotrophic Fe-oxidizing metabolism followed by heterotrophic Fe-reduction) [2]. The siderite samples exhibit light $\delta^{13}\text{C}$ enrichment (-10.60 ‰ $\delta^{13}\text{C}_{\text{PDB}}$), very fine grain size, and Corg, which also support this scenario. The samples had specific rim belts by semi-concentric outer Fe-oxide layers, fluffy pyrite-rich outer belts and siderite inner parts. Their surficial oxide layers showed evidence of degassing caused most probably by elevated temperatures. The pyrite belt excluded the possibility of a prolonged wet surface environment. ¹⁰Be nuclide values of the concretions were far above the level of terrestrial in-situ cosmogenic nuclides, but they were consistent with the lowest levels for meteorites [1]. The cut samples exhibit the measured characteristics of the STONE experiment [3] where the carbonate (dolostone) sample have suffered changes in its outer portion during the atmospheric entry ($\delta^{13}\text{C}$ and ¹⁴C values) in the baked rim and transformed mineralogy. The baked rim is the result of considerable heat effect (250-400 °C), based on mineral stability, supporting space journey. Preliminary studies based on microtexture, mineralogy and geochemistry show similarities with similar rock types of Ries ejecta. The excavated Middle and Upper Jurassic formations also contain Fe-rich (also siderite) rocks of Dogger age [4]. This raised the aim of the following calculation, as siderite can be candidate for detecting returning ejecta via atmosphere [1]. Both impact structures are thought to have formed simultaneously during the Middle Miocene by the impact of a binary asteroid [4,5]. The medium sized impact could also produce ejecta to space offering potential terrestrial meteorites according to calculations [6,7].

References

- [1] Polgári, M. et al. 2016. DOI: 10.1016/j.jenrad.2016.11.005.
- [2] Konhauser, K.O., 1998. *Earth-Sci. Revs.* 43(3):91-121.
- [3] Brack, A. et al. 2002. *Planet. & Space Sci.* 50, 7-8:763-772.
- [4] Buchner, E. & Schmieder, M. 2010. *Met. & Planet. Sci.* 45(7):1093-1107.
- [5] Stöffler, D. et al. 2002. *Met. & Planet. Sci.* 37:1893-1907.
- [6] Artemieva, N.A. 2003. 3rd Int. Conf. Large Met. Impacts. Nördlingen, Abstract #4050.

[7] Gyollai I. et al. 2017. [#2334] LPSC.

Active and cryptobiotic tardigrade survivability indexes for exoplanets

J. M. Kashyap¹

Ł. Kaczmarek²

- (1) Department of Physics, Jyoti Nivas College, Bengaluru, India.
- (2) Department of Animal Taxonomy and Ecology, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University in Poznań, Poland.

Finding life on other planets and/or moons is a fascinating area in astrobiology and planetary sciences. Up to now almost 3500 exoplanets have been found (https://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html). They represent very wide range of physical and chemical conditions. Tardigrada (water bears) are microscopic invertebrates inhabiting almost all terrestrial, freshwater and marine habitats, from highest mountains to ocean depths. Because of their ability to cryptobiosis, they are known as “the toughest animals on the Earth”. In cryptobiotic state, water bears can survive very extreme conditions (temperatures below -250 °C and up to 150 °C, high doses of UV and ionizing radiation, up to 30 years without liquid water, low and high atmospheric pressure and many toxic chemicals). However, active tardigrades are also resistant to wide range of unfavourable environmental conditions. All this makes them excellent model organisms for astrobiological studies. Due to our study we have established metric tools to predict the potential survivability of active and cryptobiotic tardigrades on rocky-water and water-gas planets in our Solar System and exoplanets. These metric tools are defined as the active tardigrade index (ATI) and cryptobiotic tardigrade index (CTI). Both are based on geometric mean of surface temperature and surface pressure calculated for considered planets. Their minimum value 0 denotes that tardigrades cannot survive whereas their maximum value 1 denotes that tardigrades will survive in a given state. Consequently, the values between 0 and 1 show us, in percentage, a chance for survive of active or cryptobiotic tardigrades on a given planet. Among known planets (except of the Earth with value 1) the highest values of ATI and CTI indexes have been calculated for TRAPPIST-1 b, Mars, Kepler-114 d, Kepler-138 d, GJ 1214 b, Kepler-445 c and TRAPPIST-1 f.

UV Environments and Biosignatures of Earth-Like Planets Orbiting White Dwarfs

T. Kozakis¹

L. Kaltenegger¹

(1) Carl Sagan Institute, Cornell University, Ithaca, NY 14850.

Earth-like planets orbiting white dwarfs would be exposed to different UV environments than planets hosted by main sequence stars of the same temperature, impacting both biosignatures and atmospheric photochemistry. We present model atmospheres and spectra of 1 AU equivalent white dwarf planets at different points in the white dwarf cooling process. Particular focus is put on changes in abundances for species that are thought to indicate habitability, along with biosignatures that can be detected by *JWST* as well other future missions. We find that cooler white dwarf models differ more from their main sequence temperature counterparts more so than hotter models, due to the greater difference in UV radiation with decreasing temperatures. These models can be used as inputs for instrument simulators for current and future missions.

THE MARTIAN DUST STRUCTURE AND MINERALOGY

P. Nørnberg¹

E. N. Bak¹, K. Finster^{1,4}, H. P. Gunnlaugsson², S. K. Jensen³

- (1) Aarhus University, Department of Bioscience, My Munkegade 116, DK 8000 Aarhus C, Denmark.
- (2) Mössbauer laboratory, ISOLDE/CERN, PH Div, CH-1211 Geneve 23, Switzerland.
- (3) Aarhus University, Department of Chemistry, 8000 Aarhus C, Denmark.
- (4) Stellar Astrophysics Center, Department of Physics and Astronomy, DK 8000 Aarhus C, Denmark.

Introduction: Mars has a red color due to ironIII oxide containing dust at the surface and in the atmosphere. Thermal Emission Spectrometer (TES) information from Mars Global Surveyor (3) show that the red color is due to crystalline hematite (α -Fe₂O₃). However, feldspar, carbonate, sulfate, pyroxene and olivine are also seen in the TES spectra (4) and it is not possible from orbit to separate the dust mineralogy information from the surface “soil” information. Dust model: Our Mars dust model uses particles (2-3 μ m) that inside consists of primary minerals which are either oxidized down to tenths of nm below the surface or have captured electrically charged nanoparticles of hematite on the surface giving the dust its reddish color. Experiments by Merrison, J.P. et al. (2010) showed that mechanical tumbling (mechanical abrasion) transformed magnetite to hematite. This experiment supports the dry comminution process indicated by Goetz et al. (2005), who also compare the chemical composition of the Martian soil with magnet-captured dust from Spirit and Opportunity. One potential problem with sampling dust using magnets is that the process of capture leads to a sampling bias with preference for more or less magnetizable particles. Therefore, we should find a way of sampling dust material without any bias. Instrument development: The XRD analyses on the NASA, MSL Curiosity rover are done primarily on drilled samples, but the first sample studied was a sample scooped from Rocknest Dune (2) where the sample consisted of a mixture of soil material in which the dust accounts for only a minor part, and hematite e.g. for only about 1 %. However, if dust could have been captured separately from the atmosphere e.g. by magnets or another tool on the MSL and taken off by e.g. tape or another mechanism that could be transferred into the target holder of the X-ray diffractometer on the MSL, it could have provided valuable quantitative information on the mineral content of the dust by Rietveld analyses. Future information: We still don't know whether the dust particles consist of primary minerals that are oxidized down to a certain depth in a dry oxidation process as suggested in Merrison, J.P. et al. (2010) or if the oxidation was caused by UV radiation or if primary particles have captured a coating of nano particles of hematite due to electrification of the dust. We could come closer to a solution to this central question by relatively simple modifications of future rover instrumentation, and at least quantify the crystalline and amorphous part of the FeIII oxides.

References

- [1] Bertelsen, P. et al. 2005. *Hyperfine Interactions*, 166,523-527.
- [2] Bish, D.L. et al. 2013. *Science*, 341, 1238932,1-5.
- [3] Christensen, P.R. et al. 2000. *J. Geophys. Res.* 105, E4, 9623-9642.
- [4] Hamilton, V.E. et al. 2005. *J. Geophys. Res.* 110, E12006. [5] Merrison, J.P. et al. 2010. *Icarus*, 205, 716-718.
- [5] Nørnberg, P. 2002, 17th WCSS, Bangkok, Symp. 25,1124.

Lunar wrinkle ridges reveal tectonic activity in the past 100 million years

A. Valantinas¹

K. M. Kinch¹

(1) Niels Bohr Institute, University of Copenhagen, Denmark (*adomas.valantinas@gmail.com).

Impacts are a dominant surface shaping process in the Solar System. Hence, these events could have played a major role in the development of life on Earth or other planets. To better understand the magnitude and dynamics of impact processes on a target planetary body, one can look at surface geomorphological features and cratering record. The Martian dichotomy boundary, irregular surface features on icy moons, Procellarum KREEP Terrane on the Moon, and finally Large Igneous Provinces on Earth, are examples of structures formed due to impacts [1-6]. In this work, we analyze young geomorphological structures and their crater size frequency distributions on the lunar nearside maria that supports the idea of a long-lasting crustal weakness due to antipodal impact at the South Pole Aitken basin. It is known that the bulk of lunar volcanism and associated tectonic processes that formed the maria were active 4-1 Ga ago [7-9]. Recently, with the help of high resolution images a number of geologically young tectonic structures have been identified by various workers. Observations of small lunar graben depths and their crater crosscutting relationships indicate recent (<50 Ma) extensional tectonism [10]. Investigations of contractional lunar lobate scarps using stratigraphy and crater size frequency distribution (CSFD) measurements has also shown that they are between 1 Ga to <100 Ma old [11,12]. In our work, we analyze several lunar wrinkle ridge systems in various lunar maria. Stratigraphic relationships and the lack of large superimposing craters suggests that wrinkle ridges in our study regions are Copernican, i.e. <1.1 Ga in age. For selected wrinkle ridge surfaces we derive model ages from CSFD measurements which result in ages below 30 Ma. Analyzed lunar wrinkle ridges appear morphologically crisp and include various degrees of pristine rocky outcrops. This suggests that they are geologically young because estimates of lunar boulder obliteration rates imply that rock populations on the lunar surface are fully destroyed in 300-1500 Ma [13-16].

References

- [1] Marinova et al., Nature 453, 2008.
- [2] Nimmo, et al. Nature 453, 2008.
- [3] Schultz and Crawford, Geological Society of America Special Paper, 141–159, 2011.
- [4] Bruesch and Asphaug, Icarus, 168, 2004.
- [5] Hagstrum, Earth and Planetary Science Letters, 236, 2005.
- [6] Meschede et al., Geophys J Int, 187, 2011.
- [7] Basaltic Volcanism Study Project, Basaltic volcanism on the terrestrial planets, 948–974, 1981.
- [8] Schultz and Spudis, Nature, 302, 1983.
- [9] Hiesinger et al., Geological Society of America Special Papers, 477, 2011.
- [10] Watters et al., Nature Geosci, 2012.
- [11] Watters et al., Science, 2010.
- [12] Clark et al. LPSC XLVI, 2015,#1730.
- [13] Basilevsky et al. Planetary and Space Science, 89, 2013.
- [14] Ghent et al., Geology, 42, 2014.
- [15] Basilevsky et al. Planetary and Space Science 117, 2015.
- [16] Ghent et al. ELS 2016,#6040.

Three-dimensional climate modelling of a terrestrial world under the gravitational perturbations of a close-in Jupiter

N. Georgakarakos¹

M. J. Way²

(1) Division of Science, New York University Abu Dhabi, United Arab Emirates.

(2) NASA Goddard Institute for Space Studies, USA.

Observing the skies over the past three decades has revealed a plethora of planetary systems whose architectures are quite different from that of our own Solar System. The discovery of planets of similar mass and size to those of the Earth is now an observational fact. This has ignited a strong interest in investigating the requirements of a habitable planet in an exoplanetary system. It has long been known that Jupiter plays a major role in the orbital parameters of Mars and its climate, but there is also a long-standing belief that Jupiter would play a similar role for Earth if not for the Earth's Moon. Using a three-dimensional general circulation model with a fully coupled ocean, we investigate what would happen to the climate of an Earth-like planet if Mars did not exist, but a Jupiter-like planet was much closer to the Earth-like planet. The Earth-like planet has a fixed obliquity of 23 degrees. We investigate two scenarios that involve the evolution of the Earth-like planet's orbit. In both cases we find that the climate would remain relatively temperate.

Subaru/HiCIAO Near-Infrared High-contrast Polarimetry Observation Towards Disk around Binary System GG Tau A

Y. Yang^{1,2}

J. Hashimoto³, S. Hayashi^{1,4}, M. Tamura^{2,3,5}, S. Mayama^{1,2}, R. Rafikov⁶

- (1) SOKENDAI (The Graduate University for Advanced Studies), Japan.
- (2) National Astronomical Observatory of Japan(NAOJ), Japan.
- (3) Astrobiology Center (ABC), Japan.
- (4) Subaru Telescope, Hawaii, the United States.
- (5) The University of Tokyo, Japan.
- (6) Institute for Advanced Study (IAS), the United States.

Currently about 200 planets have ever been discovered in binary or multiple systems. Undoubtedly, to understand their formation process, not only theoretical work but also direct observations towards the protoplanetary disks in young binary/multiple star systems is quite necessary. By high-contrast polarimetry observation with HiCIAO, a high-contrast observation instrument mounted on the 8.2-m Subaru Telescope in Hawaii, the complicated structures around the young binary GG Tau A are successfully resolved. By investigating them, we can understand how the binary system will affect the disk evolution as well as planet formation. It could be quite beneficial for us to improve current theories of planet formation process in binary systems.

Posters: Experiments

7

Primary results of the analysis of the lichen *Buellia frigida* after 1.5 years of space exposure during the BIOMEX project

T. Backhaus¹

S. Ott¹

(1) Institute for symbiotic interactions, Heinrich-Heine-Universität Düsseldorf.

Lichens are a symbiotic association between a heterotrophic mycobiont and a autotrophic photobiont. Together they build a unique thallus structure. The Lichen *Buellia frigida* is a crustose lichen which is endemic in the maritim and continental Antarctic. Samples of the lichen have been sent to the ISS for 1.5 years by the BIOMEX project. The samples were exposed in the EXPOSE-R2 unit at the outside of the ISS towards the conditions of the Low Earth Orbit (LEO). There are several methods projected to analyse the lichen samples. The lichen's viability after the LEO exposition will be analysed by a cultivation assay to check the symbiont's potential to grow and to form colonies. The results will give us information about the symbiont's potential to survive extreme extraterrestrial conditions after a long time experiment. Furthermore, the lichen's ultrastructure is planned to be analysed by transmission electron microscopy. The aim of this assay is to check which kind of defects and damages can appear due to the exposure towards LEO conditions on the level of simple cell ultrastructure. There are several more assays to analyse the lichen's viability after 1.5 years of LEO exposure planned for the future, as for instance a LIVE/DEAD staining with SYTO9 and propidium iodide. This poster presents primary results of two methods, that were already performed yet.

Detection of biomarkers of the desert cyanobacterium *Chroococcidiopsis* after the EXPOSE-R2 space mission

D. Billi¹

C. Verseux¹, M Baqué², J.-P. de Vera²

- (1) Department of Biology ,University of Rome “Tor Vergata”, Department of Biology, Rome, Italy.
- (2) German Aerospace Center (DLR), Institute of Planetary Research, Management and Infrastructure, Astrobiological Laboratories, Berlin, Germany.

The aim of the experiment BIOlogy and Mars EXperiment (BIOMEX), part of the EXPOSE-R2 space mission, is to investigate the endurance of extremophiles mixed with Lunar and Martian mineral analogues as well as analyse the stability/degradation of their macromolecules under space and Mars-like conditions¹. The results of BIOMEX will be relevant for a space proven biosignature definition and formation of a biosignature data base (e.g. an international Raman library) useful for future space missions with the main task to detect life on Mars. Among the selected extremophiles for the BIOMEX space experiment is a desert cyanobacterial strain, *Chroococcidiopsis* sp. CCMEE 029. Cyanobacterial cells mixed with Phyllosilicatic Mars Regolith Simulant (P-MRS) and Sulfatic Mars Regolith Simulant (S-MRS) were exposed to space and simulated Mars-like conditions in Low Earth Orbit (LEO) within the ESA space facility EXPOSE-R2 outside the International Space Station. Exposed samples were investigated for the detectability of biosignatures. Spectral features of photosynthetic pigments (chlorophyll a and phycobiliproteins) and of the photoprotective carotenoid pigments, were evaluated by confocal laser scanning microscopy and Raman spectroscopy, while genomic DNA preservation was assessed by using a PCR-based assay. In addition, cyanobacterial survival was assessed by testing the colony forming ability. Results are consistent with previous ground-based simulations of the mission^{2,3} and demonstrate the protection provided by P-MRS or S-MRS.

References

- [1] de Vera J-P, Boettger U, de la Torre R, Sánchez FJ, Grunow D, Schmitz N, Lange C, Hüber H-W, Billi D et al. Supporting Mars exploration: BIOMEX in Low Earth Orbit and further astrobiological studies on the Moon using Raman and PanCam technology. *Planet Space Sci* 74:103–110 (2012).
- [2] Baqué M, Verseux C, Böttger U, Rabbow E, de Vera J-P, Billi D. Preservation of biomarkers from cyanobacteria mixed with Mars-like regolith under simulated Martian atmosphere and UV flux. *Orig. life Evol. Biosph* 46, 289-310 (2016).
- [3] Baqué M, Verseux C, Rabbow E, de Vera J-P, Billi D. Detection of macromolecules in desert cyanobacteria mixed with a lunar mineral analogue after space simulations. *Orig. life Evol. Biosph* 44:209–22 (2014).

Dissemination and Communication Activities for Mars Analogue Research

P. Cabezas¹

N. Walter¹, P. Rettberg², M. Bohmeier², E. Rabbow², K. Beblo-Vranesevic², A. Perras^{3,4},
P. Schwendner⁵, C. Moissl-Eichinger^{2,6}, P. Vannier⁷, V. Marteinson⁷, E. Monaghan⁸,
P. Ehrenfreund^{8,9}, L. Garcia-Descalzo¹⁰, F. Gomez¹⁰, M. Malki¹¹, R. Amils¹¹, F. Gaboyer¹²,
F. Westall¹², C. Cockell⁵

- (1) European Science Foundation (ESF), France.
- (2) German Aerospace Center (DLR), Germany.
- (3) Medical University of Graz, Austria.
- (4) Department of Microbiology and Archaea, University of Regensburg, Germany.
- (5) University of Edinburgh, UK.
- (6) BioTechMed Graz, Austria.
- (7) MATIS - Prokaria, Iceland.
- (8) Universiteit Leiden, Netherlands.
- (9) George Washington University, USA.
- (10) Centro de Astrobiología (INTA-CAB), Spain.
- (11) Universidad Autónoma de Madrid, Spain.
- (12) Centre de Biophysique Moléculaire, CNRS, France.

The Mars Analogues for Space Exploration (MASE) project is bringing new insight about Mars potential habitability but also some new knowledge about Earth organisms and the functioning of extreme terrestrial ecosystems. The overall aim of the MASE project is to study a variety of Mars-like environments in order to further our understanding of Martian habitability, as well as our ability to detect organisms that might be present on Mars.

For communication with the scientific community, we are benefiting from Open Access scientific publications and international conferences. Mars exploration missions are massive undertakings that are managed and implemented by space agencies/industry sector in a collaborative manner. Activities performed and results obtained from MASE have a direct impact on a search for life mission design and planning. Thus, MASE is in regular contact with the European Space Agency and activities to engage with other agencies will be soon taken into action.

Providing a link between life on the Earth and life on Mars, has the potential to raise significant interest from the general public. For the project to reach this audience, we targeted journalists from science popular magazines and also organized a set of press conferences. This approach dramatically increased the visibility of the MASE project on outreach publications and media platforms. Alternative communication channels as press releases, newsletters and blog entries have also been regularly used to communicate with broader audiences with a positive outcome. Moreover, MASE scientist have been quite involved in outreach events to promote astrobiological research at local level. More recently, the MASE project have created a booklet title “A guide to Martian landscapes on Earth” to promote Mars analogues research. This hard-copy printed product resulted very successful to attract the attention of both specialized and general public audiences in conferences and science outreach events. A variety of internet based products are also used on regular basis to convey the main outcomes of the MASE project:

MASE website www.mase.esf.org Twitter @MarsAnalogues Facebook MASE @MarsAnalogues

These social media platforms have been proved to be the fastest and more effective way to internationally communicate MASE outcomes. Through Facebook, we have mostly engaged with general audience interested on space and astrobiology research topics, while Twitter audience is narrower and directly linked with the astrobiology scientific community.

Finally, the MASE project has maximized opportunities to engage with key policy stakeholders at European level. Recently, MASE was presented at “Earth Analogue Workshop” at the Research Executive Agency in Brussels. The high level goal of this workshop was to bring together a community that share interests on analogue research, fostering the sharing of best practices and lessons learnt, while exploring the potential synergies.

Duration of Microorganisms Survival in Cryopreserved State in Martian Regolith

V. S. Cheptsov^{1,2}

E. A. Vorobyova^{1,2}, A. K. Pavlov³, S. A. Bulat⁴, O. R. Kotsyurbenko^{1,5}, R. Conrad⁶,
G. A. Osipov⁷, M. V. Gorlenko¹, V. N. Lomasov⁸

- (1) Lomonosov Moscow State University, Russia.
- (2) Space Research Institute of Russian Academy of Sciences, Russia.
- (3) Ioffe Physical-Technical Institute of the Russian Academy of Sciences, Russia.
- (4) Petersburg Nuclear Physics Institute by B.P. Konstantinov of National Research Centre "Kurchatov Institute", Russia.
- (5) Yugra State University, Russia.
- (6) Max Planck Institute for Terrestrial Microbiology, Germany.
- (7) International Analytical Center, Interlab, N.D. Zelinsky Institute of Organic Chemistry, Russia.
- (8) Peter the Great Saint-Petersburg Polytechnic University, Russia.

It was assumed that the putative biosphere of Mars could be cryopreserved and had been stored for billions of years in anabiotic state like microbial communities of Arctic and Antarctic permafrost deposits have been preserved till now for millions of years. In this case the main factor causing cell's death should be ionizing radiation. We irradiated Arctic permafrost microbial community by 1 MGy dose of gamma radiation in simulated Martian conditions (pressure 1 torr, temperature -50°C) to assess duration of survival of potential microorganisms in Martian regolith in anabiotic state. Results of culturing, epifluorescence microscopy, multisubstrate testing, GC-MS of lipids, molecular cloning and Illumina sequencing of 16S rRNA genes of control and irradiated samples will be presented. In general it was found that microbial biomarkers and living cells could be reliably detected in irradiated soil samples. Resistance to 1 MGy dose of irradiation in simulated conditions proves that if there was an Earth-like biosphere on the early Mars microorganisms could survive in the surface or subsurface layers of the Martian regolith for more than tens of millions of years after climate change. The obtained data point out that the radioresistance of microorganisms being entrapped into the complex natural substrates is significantly underestimated. This work was supported by the Russian Foundation for Basic Research (grant № 13-04-01982) and by Russian Science Foundation (grant № 14-50-00029).

Preservation and detection of biomarkers in mineralized communities and its potential link to the variations in ORP

L. Garcia-Descalzo¹

F. Gomez¹, C. S Cockell², P. Schwendner², F. Westall³, F. Gaboyer³, P. Rettberg⁴,
K. Beblo-Vranesevic⁴, M. Bohmeier⁴, C. Moissl-Eichinger⁵, A. Perras⁵, R. Amils⁶,
P. Ehrenfreund⁷, E. Monaghan⁷, V. Marteinson⁸, P. Vannier⁸, M. Malki⁶, N. Walter⁹,
P. Cabezas⁹

- (1) Extremophiles Laboratory. Center for Astrobiology (INTA-CSIC) Ctra. Ajalvir Km4. 28850 Torreon de Ardoz. Madrid. Spain.
- (2) University of Edinburgh. UK Centre for Astrobiology. Old College, South Bridge. Edinburgh EH8 9YL, United Kingdom.
- (3) Centre National de la Recherche Scientifique. 3, rue Michel-Ange 75794 Paris cedex 16 - France.
- (4) German Aerospace Center. Linder Höhe, 51147 Köln, Germany.
- (5) Medical University of Graz. Auenbruggerpl. 2, 8036 Graz, Austria.
- (6) Universidad Autónoma de Madrid. Ciudad Universitaria de Cantoblanco. 28049 Madrid, Spain.
- (7) Leiden Observatory. Einsteinweg 55 2333 CC Leiden. Holland.
- (8) MATÍS ltd. Vinlandsleid 12, 113 Reykjavik, Iceland.
- (9) European Science Foundation, BP 90015, 67080 Strasbourg cedex, France.

1. Introduction Physic-chemical processes of living organisms leave tell-tale signals in the environment. The search for these signatures is one of the main goals for Astrobiology and improving and optimizing its detection regarding Mars conditions is part of the MASE project objectives. Besides, the traces of some kinds of microorganisms can be well preserved, provided that they are rapidly mineralized and that the sediments in which they occur are rapidly cemented [1]. A developed antibody multiarray competitive immunoassay (MACIA) for the simultaneous detection of compounds of a wide range of molecular sizes or whole spores and cells [2] [3] is a suitable option for biomarker detection in samples with low biomass from Mars analogue sites as well as with biomineralized microorganism communities. Moreover, biomineralization is often the first step of fossilization and produces particular chemical, structural and morphological features that can be preserved in fossil biominerals or microfossils [4] and some parameters as oxido-reduction potencial (ORP) or pH vary over the process. 2. Methods and objectives Samples from the three MASE campaigns in Iceland (Graenavatn Lake), United Kingdom (Boulby Mine) and Germany (Sippenauer Moor, Regensburg) and other one from an Alpin glacier were used to obtain enrichments and isolates as well as to extract and detect biomarkers in them. Some of the enrichments were exposed to mineralization to study, among others, the preservation of biosignatures by the assessment of antigen-antibody binding at different times. Simultaneously, the evolution of ORP through this process was monitored by two modules system (DTIVA: automated tools for microbial life detection) where ORP variations in those communities were followed through continuous measurements of nanosensors in closed chambers. An additional objective for MASE project is to develop a specific microarray with antibodies performed from natural samples and isolates from MASE sampling sites. 3. Summary and Conclusions The presence of traces from some microbial metabolic groups were detected in the mineralized communities at three different times over the fossilization process. It was undertaken by using a 168 antibody microarray for the immunoassay. There were observed variations in the resulting immunoprofiles. There seems to be a probably correlation between these changes and those in ORP through time. We consider that the simultaneous use of both approaches arises a promising tool to broaden our knowledge and improve the search for traces of life, present or past. Acknowledgements MASE is supported by European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n° 607297.

Hypothesis: ncRNA - cellular activity controller?

S. Jheeta¹

(1) NoR HGT & LUCA.

Except for DNA viruses, RNAs are widespread in biological systems and are involved in multilaterally adapted systems that control numerous cellular processes, the dimensions of which are still being explored. Principally, there are two broad categories of RNAs, namely coding and non-coding (ncRNA) and this abstract refers to the latter. The ncRNA molecules can form primary structures of approximately 22 nucleotides, as in “guided single stranded microRNAs” (ss(mi)RNA); double stranded miRNA interference segments can exist as a secondary shape; tertiary architectures are common in self-splicing group I and II introns; and, in association with proteins, quaternary structures can be formed eg RNA-induced silencing complex (RISC) and ribosomes. Such structures are multifunctional and are broadly regulatory, being involved in gene regulation as well as interfering with and the processing of both small and large RNAs. Such processing actions are well orchestrated, even to the point of efficient shredding of any unwanted RNAs - for example “used” mRNA within the cell is degraded rapidly (via RISC centres), so as to prevent them from being translated further.

Recent discoveries have also demonstrated that ncRNAs can act as riboswitches (eg glmS ribozymes), whereby they regulate their own activity; and perform genetic control by a metabolite binding mRNA. Furthermore, ncRNAs can act as triggers against invading mobile genetic elements, thereby affording protection against incoming attacks by “parasitic” nucleotide sequences, viruses, transposons, etc. ncRNAs, in addition to ribozymatic activities and carrying genetic codes such as influenza (RNA virus) are significant in that the hallmark of their modular architectural structure implies that structural and possible functional similarities exist among ncRNAs. A unique aspect of ncRNAs is that they are highly conserved and it is thought that they are molecular relics which delineated a ‘hypothetical’ entity called the “last universal common ancestor” (LUCA), which pre-dated the three domains of life, namely Archaea, Bacteria and Eukarya.

The conserved nature of ncRNAs allows to us to posit that it is highly probable that these molecules still have overall control of cellular activity. This is particularly relevant as there are large number of newly discovered ncRNAs whose functions are still to be explained and validated. During this oral presentation, I will put a case for ncRNAs being involved in the overall control of cellular activity and speculate that this ‘cellular activity control’ is passed on from one generation to the next

What links tardigrades, mitochondria and space travels?

A. Karachitos¹

M. Roszkowska², M. Osiecka¹, Ł. Kaczmarek², H. Kmita¹

- (1) Department of Bioenergetics, Institute of Molecular Biology and Biotechnology, Faculty of Biology, Adam Mickiewicz University in Poznań, Umultowska 89, 61-614 Poznań, Poland.
- (2) Department of Animal Taxonomy and Ecology, Faculty of Biology, Adam Mickiewicz University in Poznań, Umultowska 89, 61-614 Poznań, Poland.

The ability to enter into a state of anhydrobiosis, which denotes capability to survive almost complete drying (i.e., desiccation), makes tardigrades resistant to many unfavorable environmental factors including extreme temperatures, low and high atmospheric pressures as well as high doses of ionizing radiation or X-rays. Moreover, tardigrades are able to survive in the inactive form for many years. Therefore the animals are regarded as a model in astrobiology researches. It is even suggested that tardigrades could travel through space in a large meteorite and could probably confirm the theory of panspermia. The successful anhydrobiosis of tardigrades includes entering, permanent and leaving stages corresponding to the dehydration, tun and rehydration stages, respectively. Available data resulted from a few space programmes focused on tardigrades in active and tun stages indicate an important role of reactive oxygen species (ROS) production and capacity of cellular antioxidant defences to survival mechanisms but their understanding is still required to extrapolate the data to vertebrates (including humans). The main site of ROS production in cells are mitochondria. Furthermore, these organelles are known to be crucial for cell survival but their contribution to the tun stage survival has not been addressed till now. Importantly, exposure to space denotes the necessity to encounter anoxia (i.e. the absence of oxygen) whereas oxygen is crucial for animal mitochondria functioning. Therefore, we estimated the effect of anoxia on capability of anhydrobiotic tardigrades during the tun stage to recover to the active stage and combined anoxia treatment with other unfavorable environmental conditions such as low temperature and different aspects of space vacuum conditions. The functionality of mitochondria of active and anhydrobiotic individuals was monitored by application of the cell-permeant, cationic, lipophilic fluorophore. Namely, we applied tetramethylrhodamine methyl ester (TMRM), transported into mitochondria in the presence of the inner membrane potential.

The work was supported by the research grant NCN 2016/21/B/NZ4/00131 and performed with the contribution of the Biodiversity and Astrobiology Research group (BARg) at Adam Mickiewicz University in Poznań.

Field works in Morocco to support ExoMars rover to understand the habitability of Mars

A. Kereszturi¹

I. Gyollai², Zs. Kapui², G. G. Ori³, K. Taj-Eddine^{3,4}, G. Újvári²

- (1) Research Centre for Astronomy and Earth Sciences, Konkoly Thege Miklos Astronomical Institute, Hungary.
- (2) Research Centre for Astronomy and Earth Sciences, Institute for Geological and Geochemical Research, Hungary.
- (3) International Research School on Planetary Sciences, Pescara, Italy.
- (4) Ibn Battuta Centre, Cadi Ayyad University, Morocco.

In 2016 September a one week field work was realized at the analogue sites of the Ibn Battuta Centre with the support of EuroPlanet H2020 research infrastructure (No 654208), the COST TD1308 action and COOP-NN-116927 project of NKFIH. The aim was to identify analogue sampling sites using remote and local imaging and also to understand what kind of information could be gained from shallow subsurface exploration at such location. Based on the lessons learned, using the comparison of remote and in-situ images, the targeting accuracy of sampling would be improved if connections are established between the local and remote based appearance of different rocky desert types. It also turned out that dried up lakebeds need not show signatures of the past water activity in remote data in every cases, while shallow subsurface exploration could prove the former existence of lacustrine period. The selection of appropriate sampling sites in fluvial settings could be improved by analysing long, meter high open-air outcrops formed during the last fluvial episodes, which are abundant on Earth, and could be just below the resolution of the available Martian data. The understanding of the last period of geological activity could be much improved with only 20-30 cm deep excavations relatively to the information could be gained by only surface observations. Field examples ruled out regular in-situ weathering model for certain surfaces and provided information on areal flood wash. Right after sampling the acquired material should be imaged as later the aggregates fall apart during transporting, while they would have provided some information on cementation. However by this fragmentation the larger particles could be better analysed in the laboratory later as clay particles originally attached onto the grain surfaces were fallen away from them.

Brines formed by Deliquescence as a Habitat for Methanogenic Archaea

D. Maus^{1,2}

J. Heinz¹, J. Schirmack¹, A. Airo¹, S. Kounaves³, D. Wagner², D. Schulze-Makuch^{1,4}

- (1) Center of Astronomy and Astrophysics, Astrobiology Group, Technical University of Berlin, Berlin, Germany.
- (2) GFZ German Research Center for Geosciences, Section 5.3 Geomicrobiology, Potsdam, Germany.
- (3) Department of Chemistry, Tufts University, Medford, Massachusetts, United States.
- (4) SETI Institute, Mountain View, California, USA.

Life as we know it on Earth relies on liquid water. Liquid water may also be present on Mars in the form of brines due to the presence of chloride-bearing and hygroscopic salts which cause freezing point depression. Furthermore, it has been observed that in Mars analog environments such as the Atacama Desert, microbes can survive in the most hyperarid regions by deliquescence only [1]. The purpose of the experiments we report here were to recreate these observations in a controlled laboratory setting.

The habitability of briny Martian soils was investigated with an airtight deliquescence system which included two separated compartments that share the same anoxic atmosphere. The inner compartment was filled with three different Mars analog soils (either JSC Mars-1A, phyllosilicate- or sulfate-containing MRA) mixed with 30wt% sodium chloride and a cell suspension of a methanogenic archaea (either *Methanosarcina soligelidi* [2], *Methanosarcina barkeri* or *Methanobacter wolfeii*), and was desiccated under anaerobic conditions before the experiment. The outer compartment contained a saturated potassium sulfate solution to generate a stable relative humidity of 95-98%. The deliquescence of sodium chloride in the inner compartment was the sole source of liquid water for the organisms. The metabolic activity was determined by measuring the methane concentration of the common atmosphere using gas chromatography.

Our initial results show that *M. soligelidi*, an anaerobic methanogen isolated from the active-layer of Siberian permafrost, survives the desiccation process, the interaction with the phyllosilicate-containing MRA and the osmotic stress induced by different concentrations of sodium chloride during the incubation. Methane production is higher at 4°C than at the growth optimum of 28°C, showing the higher halotolerance of *M. soligelidi* to lower temperatures. However, sulfate-containing MRA and JSC Mars-1A do not provide a suitable growth substrate for *M. soligelidi*: no methane production was observed with these Mars analog soils. We show here for the first time in a laboratory setting that water provided through deliquescence is sufficient for survival of methanogenic archaea.

References

- [1] Davila, A.F. and Schulze-Makuch, D. (2016) The last possible outposts for life on Mars. *Astrobiology* 16:159-168.
- [2] Wagner, D., Schirmack, J., Ganzert, L., Morozova, D. and Mangelsdorf, K. (2013) *Methanosarcina soligelidi* sp. nov., a desiccation- and freeze-thaw-resistant methanogenic archaeon from a Siberian permafrost-affected soil *Int J Syst Evol Microbiol*, 63(Pt 8):2986-2991.

Dry riverbed in the Atacama desert: a depth profile analysis for biosignatures

P. Nauny¹

K. Simutis², J. Nainys², L. Mažutis², M. R. Lee¹, J. L. Toney¹, V. R. Phoenix^{1,3}

(1) School of Geographical and Earth Sciences, University of Glasgow, Glasgow, UK.

(2) Institute of Biotechnology, Vilnius University, Vilnius, Lithuania.

(3) School of Engineering, Strathclyde University, Glasgow, UK.

The Atacama desert is one of the best planetary analogue sites, its extreme dryness makes it an excellent environment to test the limits of microbial life. Yet, some parts of this desert may still experience rain, thus draining surface molecules down and providing water to potential underground microcosms. What could be the nature of these molecules and microorganisms, and in the subsurface would they be found?

To answer these questions, soil samples were collected at 2 cm intervals, down to 21 cm below the surface in the bed of a former river, and the temperature and relative humidity were monitored underground for approximately 48 hours. DNA and lipids were extracted from the samples. Their mineralogy and sedimentology were also analysed.

The soil samples were sands, mainly composed of quartz, calcite, and albite. Lipids were found mainly at the surface and above a clay layer located approximately 15 cm deep. Most of the lipids found are likely to have a plant origin. DNA material is almost absent, and mostly fragmented at the surface levels. However, it was possible to amplify bacterial 16S rDNA in the surface samples, and both above and below the clay layer.

Samples are now being prepared for sequencing. Early metagenomic results will be presented along with geology and georganic chemistry data.

The BOSS Experiment of the EXPOSE-R2 Mission: Biofilms versus planktonic cells

C. Panitz¹

J. Frösler², J. Wingender², H.-C. Flemming², P. Rösch³, P. Rettberg⁴

- (1) Institute of Pharmacology and Toxicology, RWTH/University Clinic Aachen, Germany.
- (2) Biofilm Centre, University of Duisburg Essen, Germany.
- (3) University Jena, Germany.
- (4) Institute of Aerospace Medicine, Germany Aerospace Center, Germany.

In the BOSS experiment (biofilm organisms surfing space), which was performed in the context of the successfully finalized EXPOSE-R2 mission, an international consortium of scientists investigated the ability of a variety of organisms to survive in space and on Mars as a function of their life style. The question in focus is whether there are different strategies for individually living microorganisms (planktonic state) compared to a microbial consortium of the same cells (biofilm state) to cope with the unique mixture of extreme stress factors including desiccation, gamma-, ionizing- and UV radiation in this environment. Biofilms, in which the cells are encased in a self-produced matrix of excreted extracellular polymeric substances, are one of the oldest clear signs of life on Earth. Since they can become fossilized they might also be detected as the first life forms on other planets and moons of the solar system and are therefore ideal candidates for astrobiological investigations. As an example for the organisms that attended the EXPOSE-R2 mission the results of the flight and mission ground reference analysis of *Deinococcus geothermalis* are presented. *Deinococcus geothermalis* is a non-spore-forming, gram-positive, orange-pigmented representative of the *Deinococcus* family which is unparalleled in its poly-extreme resistances to a variety of environmental stress factors on Earth. The results demonstrate that *Deinococcus geothermalis* remains viable in the desiccated state over almost 2 years, whereas culturability was preserved in biofilm cells at a significantly higher level than in planktonic cells. Furthermore, cells of both sample types were able to survive simulated space and Martian conditions and showed high resistance towards extra-terrestrial UV radiation. Additionally results of cultivation-independent investigations of pigment stability, membrane integrity, enzyme activity, ATP content and DNA integrity will be discussed. To conclude, biofilms exhibit an enhanced rate of survival compared to their planktonic counterparts when exposed to space and Martian conditions. This seems to indicate an advantage of living as a biofilm when facing the poly-extreme conditions of space or Mars. The findings will contribute to the understanding of the opportunities and limitations of life under the extreme environmental conditions of space or other planets as function of the state of life and aims to contribute to the understanding of the adaptation mechanisms that allow microorganisms to survive in extreme environments, possibly including space and the surface of Mars.

Trace Elements of methanogens in an astrobiological context

R.-S. Taubner^{1,2}

A. Abdel Azim^{1,3}, S. K.-M. R. Rittmann¹

- (1) Archaea Biology and Ecogenomics Division, Department of Ecogenomics and Systems Biology, University of Vienna, Vienna, Austria.
- (2) Institute of Astrophysics, University of Vienna, Vienna, Austria.
- (3) Department of Applied Science and Technology (DISAT), Politecnico di Torino, Turin, Italy.

Trace elements represent just a small part in the volume of a standard growth medium. These micronutrients are necessary for supporting the growth and metabolism of all life forms. The present study [1] focuses on hydrogenotrophic methanogens. For these anaerobic microorganisms, trace elements are of particular importance due to their usage of the archaeal version of the Wood-Ljungdahl pathway. This pathway might be used by the last universal common ancestor in a hydrothermal vent setting [2]. However, studies on the physiology of pure cultures of methanogens growing on H₂/CO₂ showed that the required optimal concentration of trace elements for microbial microorganisms is much higher than in the natural environments [3]. The level of some trace elements in natural anoxic waters was even found to be below the concentration required for growth of methanogens in pure cultures [4,5]. In this study, we investigate the effects of varying trace element concentrations on the growth of the two hydrogenotrophic methanogenic strains *Methanothermobacter marburgensis* and *Methanothermococcus okinawensis*. When varying the amount of trace elements the productivity and physiology of the two tested methanogens could be altered.

References

- [1] A. Abdel Azim, C. Pruckner, P. Kolar, R.-S. Taubner, D. Fino, G. Saracco, F. L. Sousa, S. K.-M. R. Rittmann, 2017, The physiology of trace elements in biological methane production. *Bioresource Technology* (in revision).
- [2] M.C. Weiss, F.L. Sousa, N. Mrnjavac, S. Neukirchen, M. Roettger, S. Nelson-Sathi, W. F. Martin, 2016, The physiology and habitat of the last universal common ancestor. *Nat. Microbiol.* 1 (16116).
- [3] Glass, J.B., Orphan, V.J., 2012, Trace metal requirements for microbial enzymes involved in the production and consumption of methane and nitrous oxide. *Front. Microbiol.* 3 (61).
- [4] Haraldsson, C., Westerlund, S., 1988, Trace metals in the water columns of the Black Sea and Framvaren Fjord., *Mar. Chem.* 23, 417-424.
- [5] Kremling K., 1999, Determination of trace elements. In: Grasshoff K, Kremling K, Erhardt M (eds), *Methods of seawater analysis*. 3rd edition. Wiley-VCH, Weinheim, 253-364.

Analogues for a European Extraterrestrial Sample Curation Facility

F. Westall¹

J. Zipfel², F. Foucher¹, C. Smith³, V. Debaille⁴, L. Folco⁵, J. Bridges⁶

- (1) CNRS-Centre de Biophysique Moléculaire, Orléans, France.
- (2) Senckenberg Institut, Frankfurt, Germany.
- (3) Natural History Museum, London, UK.
- (4) University of Louvain, Belgium.
- (5) University of Pisa, Italy.
- (6) University of Leicester, UK.

The aim of the H2020-funded EURO-CARES project is to create a roadmap for the implementation of a European Extra-terrestrial Sample Curation Facility (ESCF) that would be suitable for the curation of samples from all possible return missions likely over the next few decades, to the Moon, asteroids and Mars. Study and long-term curation of extraterrestrial samples imply keeping the samples as clean as possible from any possible contaminants, while ensuring they remain contained in case of biohazards, in particular when considering a Mars sample return mission. The specific objectives of the Analogues workpackage (WP5) are to evaluate specific storage conditions and handling procedures during curation and analysis of extraterrestrial materials; to identify analogue samples crucial for evaluating and defining the protocols necessary to accomplish safe and sustainable handling of extraterrestrial materials; to create a list of different types of samples that would be required for a sample curation facility (analogues and standards); to create a preliminary list of analogue materials already available; and to include recommendations for the fabrication of new artificial analogues. For the purposes of this exercise, we distinguish between different types of “analogue materials”: (1) rocks, minerals, ices, gases that have one or more physical or chemical properties similar to those expected in extraterrestrial samples returned with sample return missions; (2) reference samples of well-characterised materials with known physical/chemical properties used for testing the flow of the whole or part of the process or part of it; (3) standards of internationally recognised, homogeneous materials with known physical/chemical properties that are used for calibration (e.g. silicon for Raman spectrometry); (4) a voucher specimen, i.e. a duplicate of materials used at any stage during sample acquisition, storage, transport, treatment etc.; (5) a witness plate, i.e. a defined material left in an area where work is being done or assessed for e.g. biological, particulate, chemical, and/or organic contamination. Our recommendations are a list of essential analogue materials for a curation facility that includes natural and manufactured materials. Their physico-chemical/mineralogical properties are described in a database. The natural samples include rocks (primitive basalt, anorthosite, dolerite, tuff, suevite, mudstone, sandstone, lunar regolith, chondrite (CC,OC), HED meteorites) and minerals (olivine, pyroxene, plagioclase, Fe-Ni alloys, jarosite, magnetite, hematite, calcite, dolomite, gypsum, anhydrite, perchlorates, sulphides, Mg smectites, serpentine, amorphous silica). Gases and ices are also considered. Manufactured analogues include regolith/soil, soil mixtures (e.g. with perchlorate, ice), icy/dusty mixtures, doped samples (biological), and doped samples (organic). Acknowledgement: H2020 grant agreement No 640190; www.euro-cares.eu

An electrokinetic concept for remobilising water masses and creating essentials for the colonization of Mars

H.-A. Stavrakakis¹

E. Chatzitheodoridis¹

(1) School of Mining and Metallurgical Engineering, National Technical University of Athens, Greece.

There are controversial discussions on when humans should be sent to planet Mars. Extensive research of the planet already provided significant knowledge that such a possibility appears more feasible. When this happens, colonisation of Mars will not be fictional any longer. However, still, we will need basic installations to make the planet more hospitable to the first humans. Water is the most essential substance that we would require to establish in our first visits to Mars. We now know that water existed on Mars in the past, which is now found as ice caps or permafrost in transient liquid brines in the upper layer of the Martian soil [1]. Focusing on future colonisation, the control of these water aquifers on Mars seems essential. A scientific and technological discipline that is used on Earth to control water masses is electro-kinetics. Hydraulic flow is induced by applying an electrical field, which is then concentrated in liquid pockets/aquifers. The quality of the water can be appropriate for human consumption and utilization [2]. The transport and concentration of water masses is the result of a phenomenon called electro-osmosis, which is the basic mechanism of electro-kinetics. It can be applied on heterogeneous fluids (fluids with microparticles), or on porous media, such as soils. Other benefits of electro-osmosis include the stabilization of soils by removing the contained water and by altering the soil chemistry. Simultaneous electrolysis can provide hydrogen and oxygen gases, essential in the use as space fuel or for human respiration. We are running small-scale experiments, using different natural materials (i.e., clays, sands, powders of volcanic rocks) mixed with iron-rich rocks to investigate those possibilities and understand the process [3]. Experiments are fully automated using programmable controllers, driving a set of sensors in order to control or measure the most important physical parameters, such as soil humidity, and for measuring released gases such as hydrogen or carbon dioxide. Our experiments progress with time, improving the experimental setup but also the materials used, such as soils that simulate the Martian soil composition. We also plan to improve the experimental setup to exploit the techniques on frozen soils (i.e., permafrost).

References

- [1] Martín-Torres FJ et al. (2015) Transient liquid water and water activity at Gale crater on Mars. *Nature Geoscience*. DOI: 10.1038/NGEO2412.
- [2] Acar YB, Alshawabkeh AN (1993) Principles of electrokinetic remediation. *Environmental Science & Technology*. 27 (13): 2638–2647.
- [3] Stavrakakis H-A, Chatzitheodoridis E (2017) An electrokinetics concept for handling underground water on Mars. Poster at “Early Earth and ExoEarths: origin and evolution of life”, COST 1803 ORIGINS, 3-7 April 2017, Warsaw, Poland.

Abiogenically Relevant Self-Assembly Processes in Silica Hydrogels

K. Albdeery¹

T. P. Kee¹

(1) School of Chemistry, University of Leeds, United Kingdom.

Hydrogels have recently been identified as potential environments for abiogenesis (origins of life) in which water-activity can be modified. One such hydrogel environment of great potential significance in this regard are silica hydrogels (SHGs) as they represent an important phase in geology en route to silicification and rock formation. Like other hydrogels, SHGs have the ability to retain or absorb large amount of water in their molecular structure without dissolving in that water. In this work, are described studies directed towards self-assembly of amphiphiles in SHG environments. The driving force behind this work being to understand whether self-assembly behaviour is promoted under different conditions within a gel environment, compared to an aqueous environment. Here are described also the preparation of SHG systems as standard operating protocol (SOP), scanning electron microscopy (SEM) studies of the solid silicate matrix of SHGs, time-evolution of the gelation process via dynamic light scattering (DLS), measurements of critical micelle concentrations (CMCs) of a simple model amphiphile, sodium dodecylsulphate (SDS) under both aqueous and SHG conditions to ascertain differences in its self-assembly and measurement of critical vesicle concentrations (CVCs) of more putatively related amphiphile, mono-N-dodecyl phosphate (MNDP) and potassium oleate (PO).

Molecular dynamics simulation of reactive surface impacts

Christian Anders¹

Herbert M. Urbassek¹

(1) Department of Physics and Research Center Optimas, Technical University of Kaiserslautern, Germany.

Ice surfaces in space are subject to impacts of ions and micrometeorites depositing amounts of energy sufficient to induce chemical reactions among their molecular species. Reactive Force Field potentials (ReaxFF) developed by Van Duin et al. including all the relevant elements C, H, O, N, S, P, Si and metals - enable investigating the chemical reactions induced in molecular targets by energetic impacts. Using molecular dynamics we study the response of a typical cometary mixture of water ice and impurities (here CO₂, NH₃ and methanol) to the bombardment by ions from solar wind or planetary magnetospheres. Besides cratering and sputtering the diversity of produced molecules and their abundances can be simulated.

Molecular dynamical (MD) simulations give in principle easy access to reaction setup and analysis. Reactive force field potentials are faster than quantum mechanical methods, but computationally more expensive than classical MD with simpler interaction models, which limits the size of practicable simulations to currently about one million atoms. Thanks to parallelization e.g. with LAMMPS using MPI simulations of even larger systems might become possible.

As molecular-dynamics analogue to the Miller experiment, the production of reactive groups and building blocks of prebiotic molecules can be analyzed. We use H, He and Ne (as model for a heavier element) ions at the typical speed of solar wind particles. The fragments and products generated by the impact are analyzed in their dependence on deposited energy and their frequency of production. We find that molecular dissociations occur within 0.2 ps after ion impact and new products are formed up to a time of 1 ps; only water has a slower dynamics, due to highly mobile H atoms allowing for late recombinations until 2.5 ps. The number of dissociations, and hence also of product molecules increases from H over He to Ne ion projectiles and can be quantified by the amount of the energy deposited in the target by these ions. The most abundant products formed include CO, OH and NH₂. Reaction products are most complex for Ne impact, and include H₃O, formaldehyde (H₂CO), HO₂, and NO. Formaldehyde is important in two aspects: it is relatively frequent and known as a precursor of in the formation of sugar. In addition, molecules and radicals containing all CHON elements are formed, among which are CH₂NO, CONH, methanolamine (CH₅NO), and ethyne (C₂H₂). A second – and even multiple – impacts generates novel, and more complex product species; we found CN, CH₄, CH₃NO, methylamine (CH₃NH₂) and acetamide (CH₃CONH₂) among others, the complex species being less frequent than the simple fragments. Sputtering occurs for all projectiles, even H. The ejecta are either original molecules – in particular CO₂ – or simple fragments; By impact of solar wind particles only few product molecules are emitted leaving more complex products in the surface.

Panspermia – unifying of the nomenclature.

W. Erdamnn¹

Ł. Kaczmarek¹

- (1) Department of Animal Taxonomy and Ecology, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University in Poznań, Poland.

Since when Swedish chemist Svante Arrhenius firstly formulated a details of panspermia theory, this term has been greatly expanded and undergone many changes. Now, although we understand it more as the existence of life throughout the Universe which have been distributed by meteoroids, asteroids, comets, planetoids (on their surface or inside of it), we also consider spreading life by spacecraft and, even by radiation pressure from stars. Nowadays panspermia consider, not only, distribution of simple organisms like bacteria or algae, but also some more complex extremophilic organisms. On the other hand, it also deals with the spreading “seeds of life” in the form of organic molecules. This diversity is reflected in the existence of many terms which define a different variants of panspermia. However, the lack of a unified system of names and definitions of individual types of panspermia is very problematic. Here, we propose a simple naming system for different forms of panspermia, depending on what objects are involved in it, and how they are to be spread in space. Such unified nomenclature will facilitate further studies in this subject.

References

- [1] Arrhenius S *Worlds in the Making: The Evolution of the Universe*. New York: Harper, brothers, 1908.
- [2] Chyba C & Sagan C 1992 Endogenous production, exogenous delivery and impact-shock synthesis of organic molecules: an inventory for the origins of life *Nature*; 355, 125.
- [3] Crick F H C & Orgel L E 1973 Directed panspermia. *Icarus*; 19, 341- 346.
- [4] Kamminga H 1982 Life from space a history of panspermia. *Vistas in Astronomy*; 26, 67-86.
- [5] Lingam M 2016 Analytical approaches to modelling panspermia – beyond the mean-field paradigm. *Monthly Notices of the Royal Astronomical Society*; 455, 2792–2803.
- [6] Wesson P S 2010 Panspermia, Past and Present: Astrophysical and Biophysical Conditions for the Dissemination of Life in Space; *Space Science Review*; 156 (1), 239–252 doi:10.1007/s11214-010-9671-x.
- [7] Wickramasinghe N C 2010 The astrobiological case for our cosmic ancestry. *International Journal of Astrobiology*; 9(2), 119–129.

Small glycine-peptides on pyrite surface investigated by XPS

S. Gálvez¹

E. Mateo-Martí¹

(1) Centro de Astrobiología (CSIC-INTA), Torrejón de Ardoz, Madrid, Spain.

Understanding adsorption and self-organization processes of amino-acids and small peptides, on mineral surfaces that were likely present on early Earth, plays an important role in the prebiotic chemistry field. Wächtershäuser proposed, in addition to the mainly accepted prebiotic soup theory, that the first reactions that allow the formation of amino-acids occurred on surfaces, due to chemical reactions of organic molecules are catalysed by sulphide minerals such as pyrite [1]. In fact, a great effort has been dedicated by researchers to the interaction of organic molecules from solution on mineral surfaces, as well as the adsorption from gas phase in the last years [2-5]. Nevertheless, few spectroscopy studies of peptides from gas phase on mineral surfaces have been recently reported. In this context of prebiotic chemistry, we study the influence of molecular complexity through the adsorption of glycine, di-glycine and triglycine on pyrite surfaces by X-ray Photoemission Spectroscopy (XPS) characterization, interested in molecular self-assembly mechanisms and molecular reactivity on pyrite surface.

Glycine, di-glycine and tri-glycine adsorption on (100), (110) and (111) crystallographic planes of pyrite surface was studied under ultra-high vacuum conditions (UHV) by innovative and complementary surface techniques in the astrobiology field, like X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED). We studied that molecular adsorption complexity and surface crystallographic planes (face) has critical implications on the pyrite Surface adsorption process. Small glycine-peptides were successfully adsorbed on pyrite surface, by XPS technique we obtain understanding on small glycine-peptides/pyrite system, and chemical state of the adsorbates depending on molecular complexity, coverage and crystallographic planes of pyrite surface (100), (110) and (111). These studies contribute to the understanding of chemical reactivity on mineral surfaces, to improve our knowledge of interface process of amino-acids and peptides in prebiotic chemistry surface reactions and iron-sulphur scenarios.

References

- [1] Wächtershäuser G., *Chemistry & Biodiversity*, 4, 584, 2007.
- [2] Lambert J. F., *Origins of Life and Evolution of Biospheres*, 38, 211, 2008.
- [3] Sanchez-Arenillas M., Mateo-Marti E., *Chemical Physics*, 458, 92, 2015.
- [4] Sanchez-Arenillas M., Mateo-Marti E., *Phys. Chem. Chem. Phys.*, 18, 27219, 2016.
- [5] Sanchez-Arenillas M., Gálvez-Martínez S., Mateo-Marti E., *Applied Surface Science*, 414, 313, 2017.

Eukaryote Specific Folds: Parts of the Whole

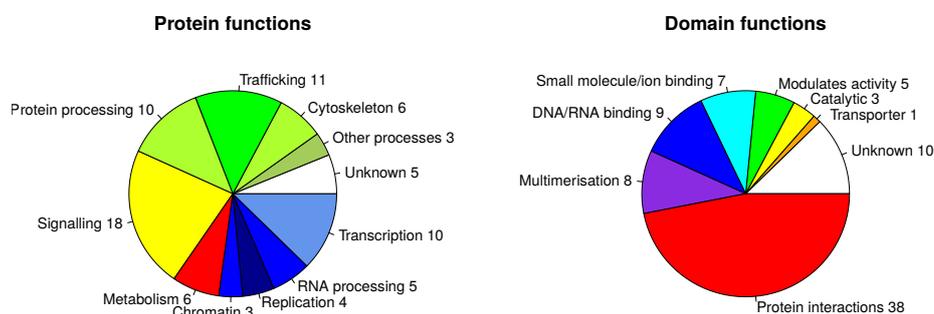
A. Kauko¹

K. Lehto¹

(1) Department of Biochemistry, University of Turku, Finland.

The origin of eukaryotes is one of the central transitions during the history of life; without eukaryotes there would be no complex multicellular life. One of the key steps was the endosymbiosis of the mitochondrion that resulted in an influx of bacterial genes with a metabolic affinity, while the information related genes are similar to the Archea. It is still unclear whether the other eukaryotic features, such as the nucleus, developed before or after the mitochondrial acquisition.

Recent studies have revealed prokaryotic roots for many eukaryotic processes. Despite of this, there exists a large number of structural superfamilies found only from Eukarya. In this study we have analysed such eukaryote specific folds. They are most commonly related to biological processes that are particularly complex in eukaryotes, but have prokaryotic roots, such as signalling, trafficking/cytoskeleton, ubiquitination and transcription. Also mRNA processing and histone regulation are represented. However, the individual domains themselves are typically involved in protein interactions or other binding processes. Often they convey protein-protein interactions as a part of a larger assembly. Therefore it seems, that eukaryote specific folds have expanded these processes to a new level of complexity. This might have taken place as a co-evolutionary process, where increasing cellular complexity and fold innovations have supported each others.



Nanobiotechnological approach for detection of life in extraterrestrial water and ice environment

D. A. Skladnev¹

O. R. Kotsyurbenko^{2,3}, V. V. Sorokin¹

- (1) Winogradsky Institute of Microbiology, Research Center of the Russian Academy of Sciences, Moscow, Russian Federation.
- (2) Lomonosov Moscow State University, Moscow, Russian Federation.
- (3) Yugra State University, Khanty-Mansiysk, Russian Federation.

The perspective for novel approaches to the search for extraterrestrial life is developing contact detection methods for astrobiology experiments. These methods require the use of high-speed and compact scientific equipment to realize a new methodology. We offer a fundamentally new, simple and universal, approach for detection of few in number biological objects (microorganisms and phages) by registration of metal biogenic nanoparticles formed in situ in tested samples - the OBNG method – Observation of Biogenic Nanoparticles Generation. The OBNG method is based on the principle that biological objects in natural water samples generate metal nanoparticles from added sterile solution of cations in the small volume of the reaction mixture 50 μl for 20–60 minutes even at +40C. We found that the formation of nanoparticles is a kinetic-controlled process favored by relatively slow ions reduction, followed by the nucleation and nanoparticles crystallization. The size and shape of biogenic nanoparticles is determined by the presence of the microorganism or phages. The argument for searching for phage particles in outer Space is that their total number in the biosphere significantly exceeding the number of cellular life forms. Many features of phages can be certainly considered as markers in searching for extraterrestrial cellular life. Indeed, a simple chemical composition of phage particles, the quasicrystalline structure, and morphological features suggest a high probability of their finding even under conditions of outer Space. With the defeat of nucleic components of phages cosmic rays (inactivation abilities of virulent phage), probably should not significantly affect the structural integrity of capsids. This means that even inactive phage particles can be detected and identified. Because phages can generate metal nanoparticles from salts, the OBNG method can be used for detection. The proposed approach allows using numerous analytical methods for recording and characterization of biogenic nanoparticles, and gives the opportunity for quick and accurately detection the presence of biogenic reducing agents of microorganisms and phages. The authors also offer the schematic design of a microfluidic chip to produce a miniature automated device based on the OBNG method. It is known that metal nanoparticles have unique optical properties (due to the phenomenon of surface plasmon resonance), highly developed surface, catalytic activity, high capacity electrical double layer, and many others. All these features make the OBNG method a novel perspective tool to explore water and ice samples for detection of biological objects in astrobiology studies.

Laboratory Simulation of the Thermal Racemization of L-Alanine in Tide Pools of Primordial Volcanic Islands

I. Wolf¹H. L. Pleyer¹, H. Strasdeit¹, S. Fox¹

(1) Department of Bioinorganic Chemistry, Institute of Chemistry, University of Hohenheim, 70599 Stuttgart, Germany.

Volcanic islands protruded from the Earth's early ocean and probably represented the only dry land in the late Hadean–early Archean. They provided a wide range of conditions and locations, such as (i) eruptions (high temperatures, lava flows, ash–gas clouds), (ii) hot lava–seawater interactions, and (iii) rock pools periodically influenced by the tides (tide pools; Fox and Strasdeit 2013). Tide pools were promising places for chemical evolution because in them organic molecules accumulated and organic reactions took place. Beside Miller-type reactions, meteorites were an important source of abiotically formed amino acids on the early Earth. Among the prebiotic amino acids, isovaline is of particular interest because in certain meteorites it has a significant L-enantiomeric excess (L-ee; Pizzarello et al. 2003). Assisted by its resistance to racemization (Gadamer 1914), meteoritic isovaline could have played a role in the origin of biological homochirality. It could also have influenced the racemization of other amino acids. We used L-alanine as a model compound to assess the effect of isovaline on the racemization of α -H- α -amino acids. To simulate a tide pool on a volcanic island, a specially designed “wet-dry apparatus” was used. In addition to the role of isovaline, we were also interested in the influence of minerals on the racemization. Therefore, a selection of probable Hadean minerals was used (Hazen 2013). The experiments were conducted at 150 °C under nitrogen atmosphere. The day length on early Earth has been estimated at 14 hours (Lathe 2006), which is why we set the duration of each wet-dry cycle to 7 hours. Every experiment took 4 days, and samples were taken in regular intervals. The samples were extracted, derivatized, and measured with gas chromatography/mass spectrometry (Fox et al. 2015). The results showed a clear influence of isovaline and minerals on the racemization rate. In the absence of minerals, L-isovaline slightly retarded the racemization of L-alanine. In contrast, the racemization was accelerated when a mineral was additionally present—regardless of which mineral was used. Especially the simultaneous presence of magnetite and L-isovaline dramatically increased the racemization rate compared to neat alanine, alanine plus isovaline, or alanine plus magnetite. The detailed results of these experiments will be presented, and their relevance to chemical evolution will be discussed.

References

- [1] S. Fox, H. Strasdeit, *Astrobiology* 2013, 13, 578–595.
- [2] S. Fox, H. Strasdeit, S. Haasmann and H. Brückner, *J. Chromatogr. A* 2015, 1411, 101–109.
- [3] J. Gadamer, *J. Prakt. Chem.* 1914, 90, 405–412.
- [4] R. M. Hazen, *Am. J. Sci.* 2013, 313, 807–843.
- [5] R. Lathe, *Icarus* 2006, 180, 277–280.
- [6] S. Pizzarello, M. Zolensky and K. A. Turk, *Geochim. Cosmochim. Acta* 2003, 67, 1589–1595.

OREOcube (ORganics Exposure in Orbit): In-Situ Spectroscopy of Organic Compounds on the International Space Station

S. Wolf¹

A. Elsaesser¹, R. Quinn², A. Mattioda², A. Ricco², F. Salama², A. Kros³, H. Cottin⁴, E. Dartois⁵, L. d'Hendecourt⁵, B. Foing⁶, Z. Martins⁷, M. Sephton⁷, M. Spaans⁸

- (1) Free University of Berlin, Berlin, DE (a.elsaesser@fu-berlin.de).
- (2) NASA Ames Research Center, Moffett Field, CA, USA.
- (3) Leiden University, Leiden, NL.
- (4) LISA, Université Paris Est-Créteil, Paris, FR.
- (5) IAS, Orsay, FR.
- (6) ESTEC, Noordwijk, NL.
- (7) Imperial College, London, UK.
- (8) University of Groningen, Groningen, NL.

OREOcube is a cubesat based space exposure platform with in-situ spectroscopy capabilities, which allows to investigate the origin and evolution of organic molecules in space and planetary environments. It is part of a new “European Exposure Facility”, which is currently under development by the European Space Agency. In order to investigate the effects of unfiltered solar and cosmic radiation on specific organic compounds, OREOcube will be attached on the outside of the International Space Station (ISS), where samples will be exposed for up to 18 months to low Earth orbit conditions [1]. Studying the photostability of organic materials directly in space avoids the limitations and technical challenges of laboratory experiments mimicking space conditions.

OREOcube leverages heritage from the O/OREOS (Organism/Organic Exposure to Orbital Stresses) nanosatellite and its SEVO (Space Environment Viability of Organics) payload [2]. In comparison to previous passive exposure platforms on the ISS, OREOcube will allow to monitor photochemical changes via in-situ UV-Vis-NIR spectroscopy while samples are being exposed. Furthermore, installation on the ISS offers the great advantage of sample return for in-depth chemical analysis on ground.

OREOcube will study the photostability of organic compounds of astrochemical importance such as porphyrins, quinones and polycyclic aromatic hydrocarbons. Samples will consist of organic thin films co-deposited on top of inorganic substrates in order to understand the role that solid mineral surfaces (e.g. iron oxide) play in the photochemical evolution and distribution of organics in our solar system and the interstellar medium [3].

Based on pre-flight testing and laboratory exposure experiments, flight samples for the OREOcube experiment are deposited on optical flats as part of a sample cell, which provides a hermetically sealed volume for the simulation of planetary and space conditions. Spectroscopic measurements are ideally suited to determine the stability, modification and degradation rates of various organic compounds, which have been identified in interstellar/planetary space, comets, meteorites or are anticipated to be present in space.

Acknowledgements: Current European funding for OREOcube is provided by the German Federal Ministry of Economics (BMW). Z.M. is funded by a Royal Society University Research Fellowship. A.M., A.R., R.Q., and F.S. acknowledge prior support from the NASA ASTID Program. R.Q. acknowledges ongoing support from the NASA Astrobiology Institute-U. Wisconsin Team.

References

- [1] Elsaesser, A., et al., *Langmuir* 30.44 (2014): 13217-13227.
- [2] Bramall, N., et al. *Planet. Space Sci.* 60.1 (2012): 121-130.
- [3] Ehrenfreund, P., & Cami, J. *Cold Spring Harbor perspectives in biology* 2.12 (2010): a002097.