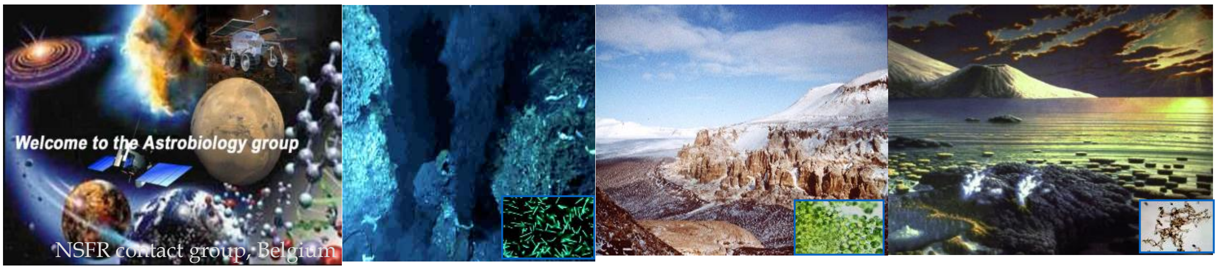

The FRS-FNRS Contact Group
"Astrobiology: from stars and planets to extreme life",
in collaboration with the EOS ET-HOME project,

is pleased to invite you on

Tuesday December 18th 2018
Room R125, building B18 (Geology department),
14 allée du 6 Août, quartier AGORA Campus du Sart-Tilman, ULiège, Liège

Invited speakers:

MICHAEL GILLON (ExoTIC Research Group, University of Liège Belgium)
"News from the TRAPPIST-1 planetary system"

ANN-CARINE VANDAELE (BIRA, Institut Royal d'Aéronomie Spatiale de Belgique)
« Methane on Mars: an update from the ongoing TGO mission"

Abstract submission before December 3rd 2018, by mail at ej.javaux@uliege.be, cc: V.dehant@oma.be

Registration is free but mandatory for logistic reasons

(send a mail at: ej.javaux@uliege.be)

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ET. HOME

Program of the annual meeting of the FRS-FNRS Contact Group "Astrobiology: from stars and planets to extreme life", in collaboration with the EOS ET-HOME project

9:30-10:00 registration, welcome coffee

BEYOND EARTH

Invited talk

-10:00-10:30 Michael Gillon (ULiège)
News from the TRAPPIST-1 planetary system

Contributed talks

-10:30-10:45 Nicolas Slotte (ULB), Vinciane Debaille, Steven Goderis
Early core formation of the asteroid Vesta revealed by HSE concentrations in eucrites.

-10:45-11:00 Cédric Gillmann (ULB), Gregor Golabek, Sean Raymond, Paul Tackley, Maria Schoenbaechler, Véronique Dehant, Vinciane Debaille
The Volatile History of Venus: from Late Veneer to Present-Day.

-11:00-11:15 J. De Keyser (IASB), M. Yamauchi, I. Dandouras, H. Gunell, R. Maggiolo
Atmospheric escape : sculpting the conditions favorable for the existence of life

MARS

Contributed talks

-11:15-11:30 Véronique Dehant (ROB, UCL)
Mission to Mars

-11:30-11:45 Vinciane Debaille (ULB)
Mars2020: why do we need martian sample return mission?

-11:45-12:00 Gloesener E. (UCLouvain), Karatekin Ö, and Dehant V
Trapping of methane by clathrate hydrates in the martian cryosphere

12:00-13:00 lunch (sandwiches)

MARS

Invited talk

-13:00-13:30 Ann Carin Vandaele (BIRA-IASB), Frank Daerden, Ian R. Thomas, Shohei Aoki, C. Depiesse, J. Erwin, L. Neary, A. Piccialli, Bojan Ristic, S. Robert, L. Trompet, S. Viscardy, Y. Willame, V. Wilquet, Giancarlo Bellucci, Jose-Juan Lopez-Moreno, Manish R. Patel, and the NOMAD Team
Methane on Mars: an update from the ongoing TGO mission

Contributed talks

-13:30-13:45 ***F. Da Pieve, E. Botek, V. Pierrard and A.C. Vandaele***
The search of habitable conditions on Mars from the perspective of the radiation environment: influence of mineralogy and atmospheric depth through epochs

-13:45-14:00 L. Demaret (ULiège), C. Malherbe, E.J. Javaux, G. Eppe
Raman spectroscopy investigations on Mars: insights into analytical methods developments for organics detection in powdered minerals

-14:00-14:15 Cedric Malherbe (ULiège), Ian B. Hutchinson, Richard Ingley, Howell G. M. Edwards and Gauthier Eppe
The importance of microstructure in biogeological interfaces of analogue samples in preparation for Mars missions

EARTH

Contributed talks

-14:15-14:30 Camille François (ULiège), Vinciane Debaille, Jean-Louis Paquette, Daniel Baudet & Emmanuelle J. Javaux
Onset of plate tectonics on Earth and implications for habitability

-14:30-14:45 Luc André (MRAC), Kathrin Abraham, Axel Hofmann and Stephen Foley
Emergence of early continental crust by reworking significant Seawater-derived Silicon

-14:45-15:00 Thomas Déhais (VUB), Sietze J. de Graaff, Pim Kaskes, Steven Goderis & Philippe Claeys
Hypervelocity impacts on Earth: importance of the comparative characterization of the distal ejecta layers

15:00-15:30 coffee break

EARTH LIFE

<u>Contributed talks</u>

-15:30-15:45 Huan Cui (VUB), Kouki Kitajima, Michael J. Spicuzza, John H. Fournelle, Adam Denny, Akizumi Ishida, Feifei Zhang, John W. Valley
Neoproterozoic superheavy pyrite tied to post-depositional processes

-15:45-16:00 Marie Catherine Sforna (ULiège), Camille François, Corentin C. Loron, Yohan Cornet & Emmanuelle J. Javaux
Probing metallic enrichment patterns in Proterozoic organic microfossils: Implication on their biological affinity, metabolisms and geochemical taphonomy

-16:00-16 :15 Corentin LORON (ULiège), Galen HALVERSON, Rob RAINBIRD, Tom SKULSKI, Elizabeth TURNER & Emmanuelle JAVAUX
Chasing Mesoproterozoic Eukaryotes: A sampling season in Arctic Canada

-16:15-16:30 Catherine Demoulin (ULiege), Yannick Lara, Camille François, Emmanuelle J Javaux
Biosignatures of modern and fossil cyanobacteria

-16:30-16:45 Yannick Lara (ULiège), Benoit Durieu, Emmanuelle J. Javaux, Annick Wilmotte
Adaptations to extreme conditions: the strategy of the Antarctic cyanobacterium ULC007

-16:45-17:00 Annick Wilmotte (ULiège), Kim Beets, Mariano Santoro, Véronique Simons, Yannick Lara, Benoit Durieu, Emmanuelle J. Javaux, Philippe Jacques, Luc Cornet, Denis Baurain
BCCM/ULC: a collection of cyanobacteria linking Poles to Space

-17:00-17:15 Javaux Emmanuelle (ULiège)
The European Astrobiology Institute

17:15 End of meeting

Departure to the Christmas market (food, drinks and craft) in Liège historical city center!

Abstracts (by alphabetical order)

Invited talks

News from the TRAPPIST-1 planetary system

Michael Gillon

Uliège Département AGO, EXOTIC research group, UR ASTROBIOLOGY

Forty light-years away in the Aquarius constellation is a tiny Jupiter-sized star so cold that emits nearly no visible light, and so little massive that it is barely a star at all. Discovered in 1999, the feeble star remained overlooked until 2015, when an international team of astronomers observing it with the TRAPPIST robotic telescope discovered several Earth-sized worlds around it. In 2017, more observations revealed that the star, nicknamed then TRAPPIST-1, is the host of an amazing compact system of seven terrestrial planets. Based on their rocky nature and on the amount of light that they receive from their star, at least three of these worlds are potentially habitable, i.e. could harbor water in liquid form, and maybe life, on their surfaces. This miniature planetary system is unique in many ways: its sheer number of Earth-sized planets, their complex resonant dynamics, the very-low mass of their « ultracool » host star, and their suitability for atmospheric characterization. TRAPPIST-1 provides us with the unique opportunity to perform the detailed comparative study of seven temperate terrestrial exoplanets, and, maybe, to reveal the presence of life beyond our solar system.
In this talk, I will review the current status of the study of this fascinating planetary system, and its exciting perspectives.

Methane on Mars: an update from the ongoing TGO mission

Ann C. Vandaele. (1), Frank Daerden (1), Ian R. Thomas (1), Shohei Aoki (1), C. Depiesse (1), J. Erwin (1), L. Neary (1), A. Piccialli (1), Bojan Ristic (1), S. Robert (1), L. Trompet (1), S. Viscardy (1), Y. Willame (1), V. Wilquet (1), Giancarlo Bellucci (2), Jose-Juan Lopez-Moreno (3), Manish R. Patel (4), and the NOMAD Team

(1) Royal Belgian Institute for Space Aeronomy (IASB-BIRA), av. Circulaire 3, 1180 Brussels, Belgium; (2) Istituto di Astrofisica e Planetologia Spaziali (IAPS/INAF), Via del Fosso del Cavaliere, 00133 Rome, Italy; (3) Instituto de Astrofisica de Andalucia (IAA/CSIC), Granada, Spain; (4) School of Physical Sciences, The Open University, Milton Keynes, UK

The NOMAD ("Nadir and Occultation for MArs Discovery") spectrometer suite on board the ExoMars Trace Gas Orbiter has been designed to investigate the composition of Mars' atmosphere, with a particular focus on trace gases, clouds and dust. This will allow for a major leap in our knowledge and understanding of the Martian atmospheric composition and the related physical and chemical processes. NOMAD will conduct a spectroscopic survey of Mars' atmosphere in ultraviolet (UV), visible and infrared (IR) wavelengths covering large parts of the 0.2-4.3 µm spectral range [1,2]. NOMAD is composed of 3 spectrometers: a solar occultation dedicated spectrometer (SO – Solar Occultation) operating in the infrared (2.3-4.3 µm), a second infrared spectrometer (2.3-3.8 µm) capable of doing nadir, but also solar occultation and limb observations (LNO – Limb Nadir and solar Occultation) [3], and an ultraviolet/visible spectrometer (UVIS – UV visible, 200-650 nm) that can work in all three observation modes [4]. Science phase started in April 2018. Since then NOMAD performed solar occultation and nadir observations using different options to test the instrument under various conditions. Several atmospheric species have been targeted, delivering profiles from solar occultation from 200km down to the surface and integrated abundances from nadir measurements. Observations optimized for the detection of methane. We will present first results from solar occultation observations.

References

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[2] Vandaele et al., 2018. Space Sci. Rev., 214:80, doi.org/10.1007/s11214-11018-10517-11212.
[3] Neefs et al., 2015. Applied Optics 54, 8494-8520.
[4] Patel et al., 2017. Applied Optics 56, 2771-2782.

Contributed talks

EMERGENCE OF EARLY CONTINENTAL CRUST BY REWORKING SIGNIFICANT SEAWATER-DERIVED SILICON

Luc André (MRAC), Kathrin Abraham, Axel Hofmann and Stephen Foley

How the felsic Archean crust grew from its mafic precursors between 3.8 and 2.5 billion years ago remains elusive and a question of large debates. Here, we present silicon isotopic constraints ($\delta^{30}Si$) on Tonalite-Trondhjemite-Granodiorite (TTG) and Granite-Monzonite-Syenite (GMS) plutons from the Kaapvaal craton, which range in age from 3.55 to 2.69 Ga. We identified consistent isotopic signatures (TTGs: $\delta^{30}Si$=0.01±0.11‰; GMSs: $\delta^{30}Si$=-0.03±0.11‰), all heavier than those ever determined for rocks which compose most of the Bulk Silicate Earth (BSE, $\delta^{30}Si$ =-0.29±0.07‰) or the Si-rich end-members of the modern continental crust: I and A types of Phanerozoic granites ($\delta^{30}Si$ =-0.19±0.08‰) and the dacitico-rhyolitic liquids differentiated from basalts ($\delta^{30}Si$ =-0.17±0.08‰). This unusual composition is explained by the melting of a metabasaltic source including significant proportions (20-30wt%) of silicified metabasalts interlayered with minor chert sediments, which were both common surface rocks at the time. Maturation of the early continental crust thus requires a pre-melting silicon enrichment of the metabasaltic precursors through Archaean silicifications consecutive to the basaltic seafloor interactions with the silica-saturated early oceans. It explains why continents are unique on Earth with regards to other rocky planets.

Neoproterozoic superheavy pyrite tied to post-depositional processes

Huan Cui[1,2,*], Kouki Kitajima [2], Michael J. Spicuzza[2], John H. Fournelle[2], Adam Denny[2], Akizumi Ishida [2,3], Feifei Zhang [4], John W. Valley[2]

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The Neoproterozoic sulfur isotope ($\delta^{34}S$) record is characterized by anomalously high $\delta^{34}S_{pyrite}$values. Many $\delta^{34}S_{pyrite}$ values are higher than the contemporaneous $\delta^{34}S_{sulfate}$ (i.e., $\delta^{34}S_{pyrite} > \delta^{34}S_{sulfate}$), showing reversed fractionation. This phenomenon has been reported from the Neoproterozoic post-glacial strata globally and is called "Neoproterozoic superheavy pyrite." The commonly assumed biogenic genesis of superheavy pyrite conflicts with current understanding of the marine sulfur cycle. Various models have been proposed to interpret this phenomenon, including extremely low concentrations of sulfate in seawaters or pore waters, or the existence of a geographically isolated and geochemically stratified ocean. Implicit and fundamental in all these published models is the assumption of a biogenic origin for pyrite genesis, which hypothesizes that the superheavy pyrite is syngenetic (in the water column) or early diagenetic (in shallow marine sediments) in origin and formed via microbial sulfate reduction (MSR). In this study, the Cryogenian Datangpo Formation in South China, which preserves some of the highest $\delta^{34}S_{pyrite}$ values up to +70‰, is studied by secondary ion mass spectrometry (SIMS) at unprecedented spatial resolutions (2 µm). Based on textures and the new sulfur isotope results, we propose that the Datangpo superheavy pyrite formed via thermochemical sulfate reduction (TSR) in hydrothermal fluids during late burial diagenesis and, therefore, lacks a biogeochemical connection to the Neoproterozoic sulfur cycle. Our study demonstrates that SEM-SIMS is an effective approach to assess the genesis of sedimentary pyrite using combined SEM petrography and micrometer-scale $\delta^{34}S$ measurements by SIMS. The possibility that pervasive TSR has overprinted the primary $\delta^{34}S_{pyrite}$ signals during late diagenesis in other localities may necessitate the reappraisal of some of the $\delta^{34}S_{pyrite}$ profiles associated with superheavy pyrite throughout Earth's history.

The search of habitable conditions on Mars from the perspective of the radiation environment: influence of mineralogy and atmospheric depth through epochs

F. Da Pieve, E. Botek, V. Pierrard and A.C. Vandaele
Royal Belgian Institute for Space Aeronomy, BIRA-IASB, Brussels, Belgium

Eventual past forms of life on Mars as well as future human missions on the red planet have been and will be strongly affected by radiation. In this context, at BIRA-IASB we are setting up an activity [1] that aims at evaluating the influence of radiation (galactic cosmic rays, solar energetic particles and XUV photons) at the very surface and at the subsurface, evaluated through detailed Monte Carlo particle transport calculations for high energy particles, based on the Geant4 tool [2], and state of the art quantum chemistry calculations for the lower energy regime [3].
Here I will present our ongoing efforts, which open the path for several possibility of collaborations with atmospheric scientists, geochemists, mineralogists:
1. Estimation of the current radiation environment (spectra and doses) at the two candidate landing sites for the next ExoMars2020 rover (Oxia Planum and Mawrth Vallis, with Oxia Planum now being the final chosen site) under different solar activity conditions. The results [4] show that both elevation (and thus atmospheric depth) and mineralogical content influence the doses received by a water sample (used as a proxy for biological target) at the surface of the two landing sites. The influence of diurnal variations of the atmosphere on the radiation environment are also studied, and compared with the observations from Curiosity [5].
2. Setting up studies on the evolution of the radiation environment through geological epoch. In this context, a co-evolution of the surface-atmosphere will be considered. different mineralogical scenarios (redox interfaces as Fe^{2+}/Fe^{3+} layer boundaries in the soil, presence of normal and deuterated water trapped in minerals, different sulfates suggesting acidic environment) as well as different atmospheric compositions will be studied, for several interesting sites: Oxia Planum, Mawrth Vallis, Nili Fossae, Gale Crater. The results will show how the radiation environment might have affected, through epochs, eventual microorganisms at the surface or in the subsurface of the planet.

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[3] Kohanoff J. and Artacho E. (2017) Water radiolysis by low-energy carbon projectiles from first-principles molecular dynamics. PLoS ONE 12(3): e0171820
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Atmospheric escape : sculpting the conditions favorable for the existence of life

J. De Keyser[1], M. Yamauchi[2], I. Dandouras[3], H. Gunell[1], R. Maggiolo[1]

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The evolution of the Earth's atmosphere is a key science theme. Mars and Venus developed atmospheres that are markedly different from that of Earth, of which the atmosphere evolved in conjunction with the appearance of life. While the geological record gives insight in surface-atmosphere gas exchanges, atmospheric evolution can never be understood without a proper assessment of the importance of atmospheric escape to space. While the current neutral escape from the Earth's atmosphere is reasonably characterized and considered negligible, the *ion escape* is more complicated because of the diversity of escape mechanisms, the complexity of ion escape routes, and the strong time variability of the amount of escape.

A variety of observations for Earth, a magnetized planet, shows that the ion outflow rate from the ionosphere is at a level of 10^0-10^2 kg/s depending on the geomagnetic, solar, and solar wind conditions. If all of these ions would escape, the escape rate is large enough to have played a major role in the past evolution of the Earth's atmosphere and even in the evolution of life. However, it is still unknown how much of these ions ultimately escape into interplanetary space, as ions may be trapped and recirculated by the geomagnetic field. Before the Cluster mission, the majority of the outflowing ions were assumed to return. This created the paradigm that "the geomagnetic field protects the atmosphere from escape". Cluster did provide some partial answers regarding outflow from the ionosphere and certain aspects of the return flow. Therefore the aforementioned paradigm is presently being challenged.

Cluster identified three major escape routes: (a) a "direct" route in the open part of the geomagnetic field where escaping ions mix into the high-latitude solar wind flow, (b) a "leaking" route from the inner magnetosphere to the magnetosheath or to the magnetotail, and (c) an "indirect" route through the nightside magnetosphere. The amount of ion escape and ion return through these routes, and the net balance, are unknown despite partial answers from Cluster. This contribution describes the different escape mechanisms and highlights the sources of energy driving them.

Some attention will also be given to the FATE mission proposal, an ESA Science F-mission proposal to study atmospheric escape from L2, beyond the point of no return for ions escaping along any of the escape routes, which addresses the question "What is the non-thermal ion escape rate from Earth as a function of solar, solar wind, magnetospheric, and upper atmospheric conditions?"

Mars2020: why do we need martian sample return mission?

Vinciane Debaille[1], and the iMOST and Euro-Cares groups

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Thanks to the past and current space missions, remarkable technological advances have been made to perform in-situ analyzes by rovers on Mars. Those on board instruments provide an extraordinary opportunity to assess the chemical composition of the geological samples down to a comfortable level for several trace elements. Martian meteorites also provide a good opportunity to study the geological evolution of Mars, even though their geological context at the surface of Mars is missing.
Two main investigations of the utmost importance cannot be performed without samples returned from Mars for analyzes in laboratories:

(1) the direct observation of morphological (fossil or not) traces of life. Up to now, no chemical signature alone, even of organic molecules, can constitute an undisputable evidence of life. Direct microscopic observations and microchemical analyses are required for searching microfossil assemblage that must be characterized for their morphological, structural and chemical properties

(2) the measurements of some key-trace element concentrations within the range of 0.1-1 ppm such as rare earth elements, a coherent suite of elements that has proven its importance for understanding geological processes, partial melting, crystallization, residual mineralogy but also alteration of samples; and more importantly, isotopic measurements. The importance of isotopic measurements is developed here below. Except for light isotopes (up to the mass of ~O), for which the distinct behavior between the different masses of the same element can be observed by several transportable techniques, larger mass spectrometry instrumentation with heavy magnet and specific curvature of the ion beam is needed to be able to measure the respective contribution of heavier isotopes. This kind of instrument, at the present time, cannot be miniaturized and is extremely sensitive to external conditions (vibrations, temperature variations…). It is thus not appropriate for space missions and renders the return of samples to Earth necessary.

Despite the high-level of technological improvements reached in space missions, high-precision measurements still require advanced technologies that can only be performed on Earth. Critically, those measurements are the angular stone for finding life on Mars with confidence, but also to solve several paradoxes we currently have about the evolution of Mars. We will present here the major questions concerning the martian geology that we aim to solve thanks to the future Mars sample return mission.

Hypervelocity impacts on Earth: importance of the comparative characterization of the distal ejecta layers

Thomas Déhais[1], Sietze J. de Graaff[1], Pim Kaskes[1], Steven Goderis[1] & Philippe Claeys[1]

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Collision and impact crater formation represent one of the most fundamental geological processes in the Solar System, with important consequences for the formation of planetary bodies and the evolution of their surface and/or atmosphere. In the case of the Earth, these high-energy phenomena can also affect life on a local and/or global scale (e.g., the Chicxulub impact [1], the Acraman impact [2]). During hypervelocity impact events, target lithologies are vaporized, melted and fractured as well as mixed with projectile (i.e., meteoritic) matter. The formation of large impact structures can be accompanied by the production of a specific type of deposits called ejecta, often distributed over vast areas. These layers are largely composed of crushed and melted dust and rock fragments. More than 2.5 crater diameters away from the source crater, these layers are called distal ejecta [3], which are not commonly preserved. Beyond 10 crater diameters from the source crater, the ejecta layer is primarily composed of glassy impact spherules of less than 1 mm, which represent solidified melt droplets and vapour-condensates. If primary crystals are present within the spherules, these impact spherules are called microkrystites, otherwise they are called microtektites. Compared to the 190 confirmed impact structures on Earth [4], only roughly 30 distal ejecta layers are currently known, and only c. 7 impact structures have been directly linked to distal ejecta layers [3].

To verify the impact origin of terrestrial spherules layers, petrographic (e.g., glassy and altered spherules, Ni-rich spinel crystals, shock-metamorphosed mineral grains), geochemical (e.g., Ir anomalies and other siderophile element enrichments), and isotopic (e.g., Cr and Os isotopic data) characteristics are mostly used. Together with tectonic, stratigraphic, and geochronogical information, these indicators for impact cratering have also been used to group different spherules layers together (e.g., Paraburdoo-Reivilo [5]) and to suggest potential source craters (e.g., spherules in the Zaonega Formation may be linked to the Vredefort impact structure [6]). This work focuses on the extensive collection of proximal and distal ejecta from various locations and time intervals available at the Vrije Universiteit Brussel. This way we aim to provide better constraints on impact spherule formation through time and to confirm or disprove the links between specific spherule layers and with particular impact structures.

References

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Mission to Mars.

Véronique Dehant[1,2]
(1) Royal Observatory of Belgium, Brussels, Belgium, (2) Université catholique de Louvain, Louvain-la-Neuve, Belgium

In an attend to better understand Mars' habitability, the space agencies send missions to Mars and lander on the surface of Mars in particular. There are several missions and experiments where Belgium is involved. ExoMars 2016, InSight 2018 and ExoMars 2018. The invited talk of our Astrobiology Contact Group meeting will be given by the PI (Principal Investigator) of the Belgian experiment NOMAD on Trace Gas Orbiter (TGO). We will concentrate our talk on the NASA mission InSight as well as on the future ExoMars ESA-Roscosmos mission to Mars where Belgium is also involved. The Royal Observatory of Belgium is participating in the SEIS and RISE experiments on InSight that has landed on Mars on November 26, as well as on the LaRa experiment on ExoMars 2020. Both RISE and LaRa are radioscience experiments. They are designed to obtain coherent two-way Doppler measurements from the radio link between a lander on Mars (the ESA-ROSCOSMOS ExoMars 2020 Surface Platform or the NASA 2018 InSight spacecraft) and the Earth over at least one Martian year. The Doppler measurements will be used to observe the orientation and rotation of Mars in space (precession, nutations, and length-of-day variations), as well as possibly polar motion, depending on the lander position. The ultimate objective is to obtain information on the Martian interior and on the sublimation/condensation cycle of atmospheric CO_2. This is also done in synergy with other instrument of ExoMars TGO (Trace Gas orbiter). Rotational variations will allow us to constrain the moment of inertia of the entire planet, including its mantle and core, the moment of inertia of the core, and seasonal mass transfer between the atmosphere and the ice caps.

Raman spectroscopy investigations on Mars: insights into analytical methods developments for organics detection in powdered minerals

L. Demaret[1,2], C. Malherbe[1,2,3], E.J. Javaux[2], G. Eppe[1]

[1] Laboratory of Inorganic Analytical Chemistry, Research Unit MolSys, University of Liege, Liege, Belgium

[2] Early Life Traces & Evolution-Astrobiology Laboratory, University of Liege, Liege, Belgium

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The exploration of Mars will reach a new milestone in 2020 with the launch of two Rover missions specifically designed to search for past or present evidence of life. Both NASA and ESA Rover will investigate ancient sites using analytical payload instrumentations capable of detecting markers of past habitability and associated potential signatures of life (biomarkers)[1,2]. These instrumentations will comprise for the first time Raman spectrometers which enable molecular identifications and quantification of organic and inorganic materials. In the context of planetary exploration, Raman spectroscopy has demonstrated valuable capabilities such as the ability to detect specific molecular markers from samples in extreme terrestrial environments including extremophiles signatures [3-6]. Obviously, the successful Raman interrogation of a microbial colonization or any structured deposits in a sample is facilitated by a comprehensive sample handling, visualization of desired sample spatial arrangements, and questioning the micrometric location of interest with the appropriate irradiation source. However, Raman analyses on Mars will be operated in-situ with single excitation sources and limited acquisition parameters on powdered materials (i.e. loss of spatial context during sample drilling and crushing). In accordance with this scenario, automated Raman procedures on solid dispersions, incorporating such constraints have to be developed for detecting randomly spread trace analyte quantities. Moreover, such methodologies are necessary for determining the scientific capabilities of flight spectrometers, and particularly the limits of detection reliably achievable for target organic compounds anticipated on Mars.

Consequently, we are developing analytical methods suitable for miniaturised spectrometers which evaluate accurately low organic amounts contained in powdered minerals. To employ acquisition modes in agreement with space instrument limitations (reduced datasets), methodologies of Raman sub-sampling (multipoint scanning) have been examined on bench-top instruments using a model sample: solid dispersions of cysteine in gypsum. These micro-heterogeneous granular dispersions (grain size 10 - 50 µm) prepared with decreasing amounts of cysteine were first evaluated by large Raman mapping for accurate sample-representative spectral collections. Confidence intervals were then established to determine the minimum required set of measurements which acceptably (at a stated level of confidence) estimates the known amounts of cysteine present. Additionally, sample surface coverage was inspected by applying different scanning patterns for an optimised sample interrogation procedure in such granular mixtures. It results that quantitative developments can support reliably the detection of organics in powdered inorganic matrices and are compatible with limited spectral acquisitions. When adapted for planetary exploration configurations, the quantitative methods established offer numerical performance values that, once transferred to miniaturised spectrometers, enable to define their detection capabilities. Preliminary tests have been carried out on a portable spectrometer with specifications (wavelength, laser spot size, irradiance range, spectral resolution[7]) representative of the Raman Laser Spectrometer (RLS) of the ExoMars 2020 mission with promising results.

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Biosignatures of modern and fossil cyanobacteria

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Cyanobacteria constitute a major group of well-diversified photosynthetic microorganisms. In paleontology, much effort and work are devoted to their study, due to their key-role in the oxygenation of the atmosphere and oceans during the GOE (Great Oxidation Event, around 2.4 Ga). Moreover, the development of oxygenated ecological niches is one of the factors linked to the diversification of eukaryotes. However, identifying extremely old microfossil structures as cyanobacteria remains often disputed. In the present day, the oldest fossil cyanobacterium (1.9 Ga) determined so far with certainty is *Eoentophysalis belcherensis* Hofmann, a microorganism forming mats and colonies in silicified stromatolites from the Belcher Islands, Hudson Bay, Canada [1]. Its affiliation to the Cyanobacteria phylum relies mainly on morphological and division mode comparison to a modern cyanobacterium, *Entophysalis* Ercegović [2].

In this context, our research project, financed by the EOS ET-HOME, mainly aims at characterizing specific biosignatures of Proterozoic cyanobacteria, based on modern ones, in order to get new insights into the origin and early evolution of cyanobacteria and of oxygenic photosynthesis. Methodologically, we are using optical microscopy, electron microscopy (SEM and TEM), Raman and FTIR microspectroscopy techniques, applied on modern specimens and microfossils, and C and N isotopes analyses applied on microfossils. This approach is expected to test the biological nature of Proterozoic microstructures, to resolve the affinities of possible prokaryotic microfossils and, therefore, to assess their taxonomic placement among cyanobacteria.

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Onset of plate tectonics on Earth and implications for habitability

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Understanding the geodynamic processes of the Early Earth is crucial because they have strong implications for the habitability of the Earth but also for other planets. The Earth is the only proven planet in the solar system with a lithosphere composed of plates that interact with each other. This process, called plate tectonics, help us to explain the global dynamics of the Earth's lithosphere. This phenomenon has played an important role in the evolution of our planet but may also have a significant impact on its sustained habitability. However, plate tectonics on Earth did not always function as today. Characterizing the transition from ancient to modern-style geodynamics regime, including plate tectonics and subduction process, is therefore important to understand the evolution of our own planet but also to compare our model to other rocky planets in our solar system and test their habitability.

Here, we characterize the oldest eclogite worldwide (2089 ± 13 Ma) discovered in the Democratic Republic of the Congo (Kasai Block). This type of metamorphic rocks is an important source of information for studying the evolution of plate tectonics, because on modern Earth, these rocks are generally only produced in the geodynamic setting of subduction. The protolith of this eclogite, a gabbro, was formed 2216 ± 26 Ma ago in a narrow basin opening in a continental environment, then was buried at great depth in the mantle by subduction (< 55 km), before being exhumed to the surface during a complete cycle of formation and closure of an ocean (called a Wilson cycle) lasting about 130 Ma. This discovery evidences a modern-style plate tectonics operating since at least 2.2-2.1 Ga. It highlights the fundamental differences between the ancient Earth, without plate tectonics, and the modern Earth, as we know it today. The appearance of plate tectonics had important impacts on Life evolution on our planet, with an increased supply of nutrients, increased diversity of ecological niches and geographic isolation leading to increased biodiversity, variable climatic conditions and oceanic circulation, as well as volcanic gases of different composition that may have influenced the composition of our atmosphere.

Trapping of methane by clathrate hydrates in the martian cryosphere

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Several detections of methane in the atmosphere of Mars have been reported from Earth-based and Mars orbit instruments with abundances ranging up to tens of parts per billion by volume (ppbv). Recently, the Curiosity rover observed seasonal variations of CH_4 background levels with an average mixing ratio of 0.41 ppbv and episodic releases of 7 ppbv. Although the methane sources are still unknown, this gas may have been stored in reservoirs of clathrate hydrate in the martian cryosphere where thermodynamics conditions are favorable to their presence.

In this study, the fraction of methane trapped in clathrate hydrates is investigated under martian conditions for different gas mixtures including main components of the martian atmosphere. As the calculated abundance ratios in multiple guest clathrates can significantly vary when using different potential models to estimate the guest-clathrate interactions, two models are tested here: a first approach based on the Kihara potential and a second based on an atom-atom interaction potential model. In addition, since most of the methane generation mechanisms imply H_2 production, trapping of CH_4 in the presence of H_2 is considered as well.

The EUROPEAN ASTROBIOLOGY INSTITUTE

Emmanuelle Javaux and the other EAI members of the temporary board

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Fundamental questions in science like "How and when did life emerge on Earth?", "How did our solar system and life evolve and how will it develop in the future" and "Is there life on other celestial bodies" will not be answered by one discipline alone but require a concerted and coordinated approach involving many researchers with seemingly unrelated scientific backgrounds. Also, the European research landscape is rapidly changing on a global scale. Boundaries between disciplines disappear and new cross-disciplinary fields emerge. Astrobiology is one of them. Research in such fields requires interaction and exchange of ideas and new results between scientists from many countries and disciplines, a task that only larger research communities, like the European Research Area, can accomplish.

In order to take Astrobiology-related research forward and to prevent a counterproductive fragmentation of the European Astrobiology research community through duplicate or excessively overlapping initiatives and structures, the AstroMap Report (drawn up under the EU FP7 programme) unequivocally recommends the creation of a pan-European platform for research, training outreach and dissemination in Astrobiology. The European Astrobiology Institute (EAI) aims to function as such an entity. Such an institute is required to maintain Europe's leading position in this interdisciplinary field, compared to other countries and regions. The EAI will closely collaborate with several related European organisations, including the European Space Agency (ESA) and the European Astrobiology Network Association (EANA), but act as a network of institutions that fundamentally differs from existing bodies.

A consortium of representatives of European Research Organisations, which was formed as a result of the initiatives of the COST Action "Origins and Evolution of Life on Earth and in the universe" (Action Identity TD1308), EANA and the Erasmus+ Strategic Partnership "European Astrobiology Campus" (EAC), has taken the initiative to create a virtual institute named the "European Astrobiology Institute" (EAI) with the ambition of enabling Europe to emerge as a key player in Astrobiology and to develop a general spirit of cooperation and collaboration throughout the European planetary science community. In this way, these communities continue to keep the momentum of the COST Action and EAC initiatives whose grant periods terminated during the Academic Year 2017/2018 and which received excellent reviews (both initiatives were highlighted as success stories by the EU).

GENERAL AIM OF THE EAI

The European Astrobiology Institute (EAI) will be a consortium of European research and higher education institutions and organisations as well as other stakeholders and aim to carry out research, training, outreach and dissemination activities in Astrobiology in a comprehensive and coordinated manner, thereby securing a leading role of the European Research Area in the field.

OBJECTIVES

The EAI has the following objectives:

- Perform ground-breaking research on key scientific questions in Astrobiology (which will be periodically reviewed) requiring a cooperative interdisciplinary approach;
- Disseminate high-quality results of these efforts effectively in the scientific community;
- Provide interdisciplinary training for students and early career scientists in Astrobiology;
- Engage in education on Astrobiology on all levels;
- Liaise with industry to foster collaborate on technological developments that are relevant to Astrobiology research and beneficial to Europe as a whole;
- Coordinate outreach activities of European astrobiologists to the general public, industry and all other relevant stakeholders;
- Act as an advisory body and provide high-quality expertise to European research organisations and decision makers on European scale;
- Ensure the necessary financial means to carry out these activities through a coordinated approach to European funding agencies.

MEMBERSHIP
EAI will be open to all entities who wish to sign the Memorandum of Understanding (MoU). The Statutes of the EAI define EAI, its structure and its objectives as well as the rights and obligations of these Participating Entities. By signing the MoU, the Participating Entity agrees to fulfil all its obligations towards the Institute.
The following forms of memberships exist for Participating Entities*:*
Core organisations (National, Regional and European Research Organisations and consortia)
Participating institutions (Higher education and research institutions and individual research entities or substructures of those)
Affiliated groups (smaller groups of researchers inside an institution or other consortia interested in Astrobiology research).

KEY RESEARCH AREAS OF THE EAI AND ASSOCIATED SCIENTIFIC QUESTIONS

Formation of planetary systems and detection of habitable planets and moons
How are planetary systems formed?
How do the conditions of the formation environments (galaxy, protoplanetary disk) influence the formation of habitable planets?
Which factors define habitability?
How can we detect extrasolar habitable planets and satellites?
Co-evolution of early Earth's geosphere, atmosphere and biosphere
How did physical, chemical, geological and biological processes co-evolve on Earth?
How did habitability evolve on early Earth?
Which conclusions can we draw for other planets from studies of the Earth?
Early life and life under extreme conditions
In which environment did life first emerge (Darwin's little warm pool or some more extreme environment)?
Which boundary conditions exist for life and what can they tell us about early terrestrial and the possibility of extraterrestrial life?
The pathway to complexity: From simple molecules to first life
Where and how did the complex organic molecules necessary for life originate (space, atmosphere, surface) and how were they delivered?

How does the environment affect the production and stability of complex organic molecules?
How did the formation of biopolymers and self-assembly of first cells proceed?

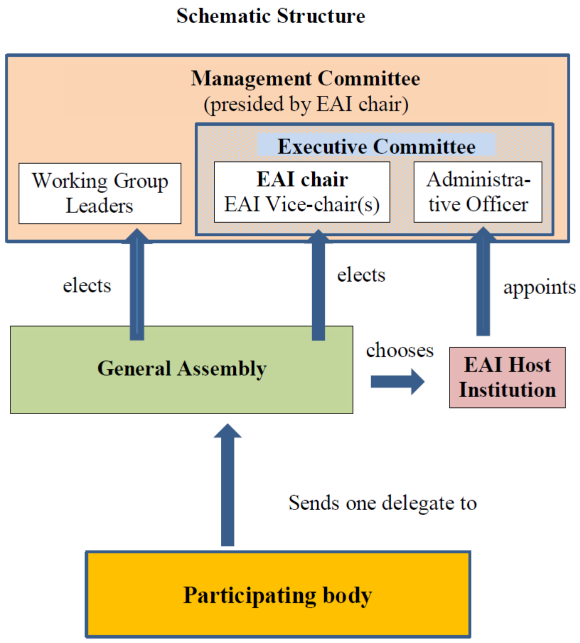
Search for life in early and extreme terrestrial environments and on other planets

Which strategies should we employ for tracing early terrestrial as well as extraterrestrial life in environments?
Which (combination of) individual biosignatures (chemical, geological, spectroscopic, others) and tracers of life present in these environments would be seen conclusive for extant and extinct life?
Which novel methods and technologies can be developed to detect life?

Historical, philosophical, societal and ethical issues in astrobiology

How did our ideas about the origin of life develop?
Which views about extraterrestrial life exist in different cultures?
Which philosophical, societal, political, juridical and ethical issues are raised by the search for life on other planets and moons?
All these fundamental research questions require a concerted effort by scientists from different fields

The Interim Board suggests the creation of two types of Working Groups to coordinate the activities of the EAI: *Thematic working* groups on scientific themes and *Activity Working Groups* addressing different activities like training, education, outreach, etc.



The Volatile History of Venus: from Late Veneer to Present-Day.

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We study the volatile history of the atmosphere of Venus and how it evolved depending on volcanism, atmospheric escape and collisions with large asteroids. Specifically, we investigate the long-term evolution of volatiles in the atmosphere of Venus, using self-consistent numerical models of global thermochemical convection coupled with both an atmospheric evolution model and a late veneer N-body model.

We have developed a coupled numerical simulation of the evolution of Venus, striving to identify and model mechanisms that are important to the behaviour of the planet and its surface conditions. Currently the simulations include modelling of mantle dynamics, core evolution (magnetic field generation), volcanism, atmospheric escape (both hydrodynamic and non-thermal), evolution of atmosphere composition, and evolution of surface conditions (greenhouse effect) and the coupling between interior and atmosphere of the planet. We have also modelled the effects of large meteoritic impacts on long term evolution through three aspects: atmosphere erosion, volatile delivery and mantle dynamics perturbation due to energy deposition. We compare the state of the atmosphere of Venus observed at present-day to that obtained from the 4.5 Gyr evolution simulations.

Venus' proximity to the Sun caused extremely efficient early hydrodynamic escape, removing most of this water within the first 100 Myr of its evolution, contrasting with more limited water loss from Earth. Later escape processes are mainly non-thermal and much less efficient but longer lived. They compete with volcanic degassing to keep water content in the atmosphere of Venus at the very low level observed at present-day (20ppmw.). The interaction of non-thermal escape and the volcanic source would be the origin of the high D/H ratio observed in the atmosphere of the planet. This does not, however, precludes a wet Venusian mantle as, at the surface pressures observed today, only 0.1 to 1% of the actual lava water content at most is likely to be released into the atmosphere. CO_2 degassing is not affected in the same way and is likely to be comparatively larger.

By varying the composition and size distribution of the late veneer material, we show that LV impactors should preferentially have a composition similar to that of Enstatite/ordinary chondrites, as opposed to carbon chondrites (volatile rich) to reproduce present-day conditions. CC contribution is thus limited to 0-2% of the total LV mass. Our study thus suggests that the late veneer delivered to Venus was preferentially dry, confirming previous studies based on isotopes for Earth and Mars. Venus and its atmosphere have therefore not received any major volatile delivery after the end of the magma ocean stage and the majority of the volatiles was delivered to the terrestrial planets already during planet formation.

Adaptations to extreme conditions: the strategy of the antarctic cyanobacterium ULC007

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ABSTRACT

In Polar regions, freshwater ecosystems range from cryoecosystems and ice shelf meltwater ponds to perennially ice-covered lakes where conspicuous benthic microbial mat communities constitute most of the biomass. In these mats, cyanobacteria form the matrix in which other microorganisms can live, and where they are the key primary producers and main drivers of the carbon and food webs.

To provide a better understanding of the survival strategies of Polar mat-forming cyanobacteria, we investigated the genome of a strain of the widely distributed Antarctic cyanobacterium, *Phormidium priestleyi* ULC007. We used high-throughput sequencing technologies to investigate its geographic distribution and genome evolution. More precisely, we investigated the abundance of genes involved in cold adaptation and circadian oscillation.

In cold habitats, low temperatures lead to the success of particular organisms featuring adaptations to molecular and cellular disturbances such as higher rigidity of membranes, reduction of enzyme-catalyzed reactions, and reduction of solute transport. Our main results underline the importance of functional categories of genes involved in the production of key molecules for the survival of *P. priestleyi* in cold conditions (e.g. synthesis of exopolysaccharides, chaperone proteins, fatty acids and phospholipids).

Chasing Mesoproterozoic Eukaryotes: A sampling season in Arctic Canada

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The Dismal Lakes Group outcrops in the Northwestern Territories and Nunavut in Canada. This Mesoproterozoic succession is a well constrained, overlying the 1590±3 Ma Hornby Bay Group and underlying the 1267±2 Ma Coppermine River Group. The Group record shallow marine paleoenvironment in an alternation of organic-rich shale and stromatolitic dolostone with subordinate layers and nodule of chert. First micropaleontological studies were conducted in the eighties by Bob Horodyski and colleagues in cherty and shale material. Only a poor diversity of prokaryotic microfossils was reported. In the summer 2017, a field expedition supported by the Agouron Institute and co-organized by the Geological Survey of Canada (Ottawa, ON) and the university of McGill (Montreal, QC) was led in the Artic Canada, to sample more material for microfossil investigations. Preliminary results show an important diversity of eukaryotes for this period of time, including new taxa unknown to science. This research is part of a PhD thesis supported by the FNRS and ERC STg ELITE.

The importance of microstructure in biogeological interfaces of analogue samples in preparation for Mars missions

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In 2020, Raman spectrometers will be deployed on Mars to study the composition of the surface when the ExoMars (ESA/Roscosmos) and the Mars 2020 (NASA) rovers will be launched[1]. For the first time, samples recovered from up to 2 meters down the surface of Mars will be interrogated with the ExoMars drill. Raman spectrometers have the capability to detect geological substances constituting the rocky surface of Mars (inorganic molecules and inorganic molecular ions). The nature of rocks on the surface of Mars will provide information about the habitability of the planet. In addition, Raman instruments have the ability to detect potential biological-derivative substances, often referred to as biomarkers (organic molecules originating from extent or extinct living organisms). In preparation for ExoMars, studying the detection capability of miniaturized Raman spectrometers is essential, in particular for instruments developed for space missions (compromised by the associated challenging constraints such as minimal power budget, mass budget, data budget and overall envelope). We present a comparison of the capability of a number of Raman spectrometer configurations to characterize a selection of 3 samples recognized as terrestrial analogue samples for the surface of Mars: (a) desert varnish samples[2], which are mineral coatings often associated with living organisms in many stable extreme environments on Earth; (b) benthic gypsum crusts colonized by microorganisms, which excrete some photo-protective pigment such as carotenoids[3]; and (c) fossilized carbonaceous fumarole, which inner part is covered with iron oxide and colonized by microorganisms. In particular, we will compare spectral data recorded with benchtop instruments and miniaturized spectrometers with operating modes similar to the future ExoMars Raman Laser Spectrometer. We will also discuss important how the recognition of microstructures revealed by Raman imaging can help in recognizing biogeological formation.

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Probing metallic enrichment patterns in Proterozoic organic microfossils: Implication on their biological affinity, metabolisms and geochemical taphonomy.

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The Eukarya domain evolved early in Earth history, but little is known on the identity of these early organisms and their metabolisms. Metals, which are widely used by all microorganisms, could act as indicators of past microbial activity in the rock record if we are able to distinguish the influence of microorganisms on metal distribution and speciation from the influence of abiotic processes. The distribution of bioessential metals (Fe, Mn, Cu, Zn, Ni, Co, Se and As) within eukaryotic and prokaryotic microfossils from two Proterozoic sedimentary basins in Mauritania and in DR Congo was characterized with high resolution synchrotron X-ray microfluorescence in order to identify particular metal distribution patterns associated with specific processes controlling the observed distribution (metabolism, detoxification processes or diagenesis).

We report here the preliminary results obtained on *Arctacellularia* microfossils. *Arctacellularia* is characterized by barrel-shaped cells attached in chain which frequently display intracellular inclusions (ICI). These inclusions are thought to be condensed cytoplasmic remains and therefore possibly represent an invaluable archive to study *Arctacellularia* metabolism. The acquisition of the transition metal distribution was challenging due to the low concentration of the metals of interest in the considered microfossils. However, we were able to identify different patterns of distribution within the microfossils. Fe, Cu and Zn are diffuse in the organic walls or contained within small sulphides at the surface, suggesting passive absorption of metals by the cell walls and *in situ* sulphides precipitation during diagenesis. In addition to be diffuse in the walls, Ni is systematically concentrated within the intracellular inclusions. Rarely associated with Fe, this could suggest that its concentration could have been biocontrolled. *Arctacellularia* has been previously interpreted as fungi based on its morphology. Ni accumulation could be linked to detoxifying processes as observed in modern filamentous fungi. Another interpretation could be that when chlorophyll is degraded during the diagenesis, it degrades as porphyrin, Ni species being frequent occurrences. If confirmed it would mean that *Arctacellularia* was not a fungi but a phototrophic organism.

Overall, this study shows the potential of this approach to provide fundamental new insights on the identification of the Precambrian microfossils and their metabolisms.

Early core formation of the asteroid Vesta revealed by HSE concentrations in eucrites.

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Highly siderophile elements (HSE: Os, Ir, Ru, Rh, Pt, Pd, Re, Au) are characterized by a strong affinity for iron with respect to silicate materials.

Hence, these elements have been partitioned into the metallic core of planetary bodies during early differentiation, leaving their silicate portions stripped of HSE. Thus, the HSE concentrations in the silicate mantle and crust mainly depends on the HSE metal-silicate partition coefficients but also the replenishment during and after core formation by the accretion of chondritic materials.

Here we show that the HSE concentrations in the silicate crust of Vesta capture the competition of both HSE depletion and enrichment by core formation and chondritic intake, respectively.

We analyzed five unbrecciated eucrites previously dated by Al-Mg systematics. These eucrites can be divided in two distinct populations based on their chondrite-relative HSE abundances. We suggest that the discrepancies in HSE depletion reflect the progressive decrease of core segregation intensity in favor of the intake of HSE by chondritic accretion in the vestan mantle within 1 million years.

Our results highlight that core segregation was an efficient and progressive process that can be tracked down by using HSE.

BCCM/ULC: a collection of cyanobacteria linking Poles to Space

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The BCCM/ULC public collection funded by the Belgian Science Policy Office (BELSPO) aims to gather a representative portion of the cyanobacterial diversity with a focus on Polar biotopes (e.g. limnetic microbial mats, soil crusts, cryoconites, endolithes). It represents an exclusive Biological Resource Centre (BRC) where characterized polar cyanobacterial strains are available for researchers to study the taxonomy, biogeography, evolution, synthesis of secondary metabolites, adaptation to harsh environmental conditions, and genomic make-up. It currently holds 190 strains, including over 120 of Polar origin (online catalogue: http://bccm.belspo.be/catalogues/ulc-catalogue-search). Living cultures are regularly transferred, and the majority are also cryopreserved (as back-up), in order to assure their preservation and the rapid delivery of strains to clients for fundamental and applied research in both academia and industry. Genomic DNA is also available on request. The collection has obtained the ISO 9001:2015 certification for deposit and distribution of strains, as part of the multi-site certification for the Belgian Coordinated Collections of Microorganisms (BCCM) consortium. A polyphasic approach based on morphological and molecular identifications (based on SSU rRNA sequences) show that the strains belong to the Synechococcales, Oscillatoriales, Chroococcidiopsidales, Pleurocapsales, and Nostocales orders. This large diversity renders the BCCM/ULC collection particularly interesting for taxonomic, biogeographic and phylogenomic studies. Furthermore, the sequencing of the genomes of several strains has started. The BRC also aims to become a source for researchers to study further applications of cyanobacteria in astrobiology as shown by investigations of the resistance to desiccation and radiation of strains of *Chroococcidiopsis sp.* dominating rock-dwelling communities in extreme dry environments [1]. In paleontology, cyanobacteria represent model organisms thanks to their fundamental role in the oxygenation of the atmosphere and oceans during the Great Oxidation Event. Lastly, the mat-forming cyanobacterial strains may represent “critical organisms” in the investigation of the factors that determine the boundaries of microbial survival and growth on Earth and in the space environment, by virtue of the fact that they are components of microbial mat model systems which are more and more used to elucidate Earth’s past and the detection of life’s biosignatures.

[1] Billi C. et al. (2013). Cyanobacteria from Extreme Deserts to Space. *Advances in Microbiology, 2013, 3*, 80-86.