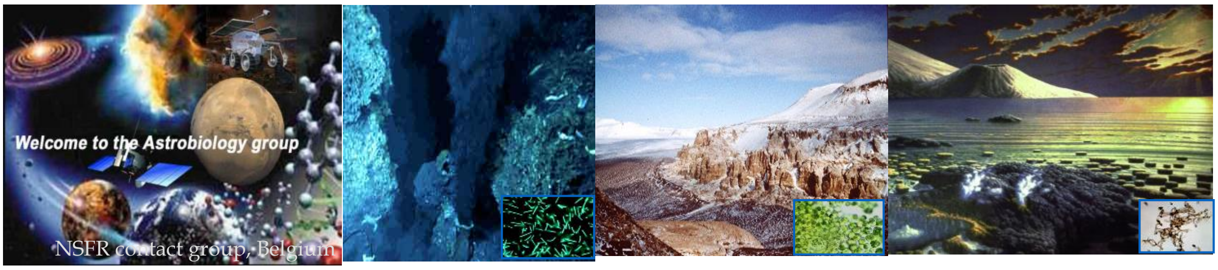


Abstracts & Program

FNRS Contact Group “Astrobiology: from stars and planets to extreme life” – Annual meeting 2015 & IUAP Planet TOPERS meeting – third annual meeting

Friday 27th November 2015

“Salle Méridienne”of the Royal Observatory of Belgium
rue circulaire/Ringlaan, 3, Brussels

Invited speakers:

Nicolas Mangold (Univ. Nantes): "Water on Mars"
Doris Breuer (DLR Berlin): "Geodynamics of planets and habitability"
Johan De Keyser (Belgian SPace Aeronomy): "Latest results from Rosetta"

Organization: V. Dehant & E. Javaux, with the help of J. Schmetz & M. Guadagnano

Program

9:00-13:00: IUAP Planet TOPERS meeting – third annual meeting (closed)

***13:05**: Lunch (open)*

13:55: Welcome

14h00 Invited talks:

- **14:00-14:40**: **Nicolas Mangold** (Univ. Nantes): "Water on Mars"
- **14:40-14:55**: Table ronde involving all participants and including point of view of **Emmanuelle Javaux, Veronique Dehant and Planet TOPERS members** – discussion on latest results on habitability
- **14:50-15:30**: **Doris Breuer** (DLR Berlin): "Geodynamics of planets and habitability"
- **15:30-16:10**: **Johan De Keyser** (Belgian SPace Aeronomy): "Latest results from Rosetta"

***16:10** Coffee*

16h25-18h30: Contributed talks

- **16h25**: **Tilman Spohn** (DLR Berlin) on "Planetary Evolution and Life: Astrobiology from a Planetary Science Perspective"
- **16h45**: **Bernard Charlier** et al (ULg): "Magmatism on Mercury: composition, abundance of sulfur and oxygen fugacity
- **17h00**: **Frank Daerden** and Lori Neary (Belgian Institute for Space Aeronomy): "A solar escalator on Mars: Self-lifting of dust layers by radiative heating"
- **17h15**: **Jeremie Beghin** et al. (ULg): "Palaeoecological model of the Mesoproterozoic Taoudeni basin."
- **17h30**: **Camille François** et al (ULg): "Proterozoic time constraints on the deposit of the Mbuji-Mayi Supergroup, Democratic Republic of Congo (DRC)"
- **17h45**: **Loïc Trompet** (Belgian Institute for Space Aeronomy): "The NOMAD Instrument on-board the ExoMars Trace Gas Orbiter: current status"
- **18h00**: **Séverine Robert** (Belgian Institute for Space Aeronomy): "Expected performances of the NOMAD instrument onboard ExoMars TGO"

Abstracts (alphabetical order)

PALAEOECOLOGICAL MODEL OF THE MESOPROTEROZOIC TAOUDENI BASIN (MAURITANIA)

J. BEGHIN[1]*, S. W. POULTON[2], N. GUENELI[3], J. J. BROCKS[3], J.-Y. STORME[1], C. BLANPIED[4] AND E. J. JAVAUX[1]

[1]Department of Geology, University of Liège, Liège, 4000, Belgium (*correspondence: jbeghin@ulg.ac.be); [2]School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom; [3]Research School of Earth Sciences, The Australian National University, Canberra, ACT 2601, Australia; [4]TOTAL, Projets Nouveaux, Paris, France

The mid-Proterozoic rock record preserves a relatively moderate diversity of early eukaryotes, despite the early evolution of fundamental features of the eukaryotic cell. Common hypotheses involve the redox state of stratified oceans with oxic shallow waters, euxinic mid-depth waters, and anoxic and ferruginous deep waters during this time period. Mid-Proterozoic eukaryotes would have found suitable ecological niches in estuarine, fluvio-deltaic and coastal shallow marine environments near nutrient sources, while N_2-fixing photoautotrophs bacteria would have been better competitors than eukaryotic algae in nutrient-poor niches. Here, we present the first palaeoecological model of the late Mesoproterozoic Taoudeni basin, Mauritania, northwestern Africa. Sediments were deposited under shallow waters in pericratonic and epicratonic marine environments. Both microfossil assemblages and iron speciation were analyzed on the same samples, with the aim of better understanding the palaeoecology of early eukaryotes. Our study of the palaeobiodiversity shows the presence of prokaryotes and eukaryotes in the basin. Palaeoredox conditions rapidly fluctuated from anoxic to oxic states across the basin, but in terms of anoxic episodes, ferruginous conditions dominated in epicratonic environments, while euxinia was prevalent in pericratonic environments. A relatively higher fossil eukaryotic diversity, both in terms of richness and abundance, was observed in the more proximal environments during the marine transgression. Our results could possibly suggest that both the availability of molecular oxygen and nutrients are needed for a high eukaryotic diversity and could confirm a previous hypothesis suggesting that mid-Proterozoic eukaryotes would have found suitable ecological niches in shallow marine environments near nutrient sources.

GEODYNAMICS OF PLANETS AND HABITABILITY

Doris Breuer

Institute of Planetary Research in Berlin, DLR

Habitability is commonly understood as the potential of an environment (past or present) to support life of any kind. As such, the presence of liquid water at or close to a planetary surface is an important aspect in the habitability discussion because terrestrial life requires water. The existence of liquid water, however, is strongly linked to the interaction between the planetary interior and the atmosphere. This interaction is mainly caused by volcanic outgassing of the planetary interior via partial melting and recycling of crustal material including volatiles back to the mantle – the latter can also occur via crustal delamination in addition to plate tectonics. Volatiles such as H_2O and CO_2 present in the mantle minerals are preferentially enriched in the liquid phase during melting. As a consequence, they will be extracted from the mantle during the crust formation process. A depletion of volatiles on the mantle influences on the other hand the mantle rheology and thus the interior dynamics. Part of the extracted volatiles will then be outgassed into the atmosphere through extrusive volcanism and part will remain in the lower crust. The outgassed volatiles will strongly influence the surface temperature conditions via greenhouse warming. To 'track' volatiles of a planet is thus of particular importance for its habitability but also its interior dynamics. Another aspect of the volatile cycle is related to the question of how much volatile were stored in a planet during its formation and how much got lost during loss processes such as magma ocean crystallization. The presentation will review the state of the art interior evolution of terrestrial planets with an emphasis on the volatile distribution with time and its consequence of the mantle dynamics.

Invited author:

Doris Breuer studied geophysics in Münster, Germany, and currently works at the German Aerospace Center (DLR), Institute of Planetary Research in Berlin, where she is Head of the Department of Planetary Physics since 2004. She is also Associate Professor at the Institute de Physique du Globe de Paris (since 2005). She is involved in scientific teams for various space experiments, such as HP3 (Heat Flow and Physical Properties Package) for ExoMars, MORE (Mercury Orbiter Radioscience Experiment) and BELA (BepiColombo Laser altimeter) on the BepiColombo mission to Mercury. Her main fields of research are the thermo-chemical evolution, the mantle dynamics and the interior structure of planetary bodies. Doris likes music, movies and reading.

MAGMATISM ON MERCURY: COMPOSITION, ABUNDANCE OF SULFUR AND OXYGEN FUGACITY

Bernard Charlier[a], Olivier Namur[b], Camille Cartier[a]

[a]University of Liege, Department of Geology, 4000 Liege, Belgium; [b]University of Hannover, Institute of Mineralogy, 30167 Hannover, Germany

Mercury is the innermost planet of our solar system. It is made of a very large core (65 wt.% of the planet) and a thin mantle (420±30 km). The surface of Mercury is a secondary crust produced during volcanic eruptions dominantly dated at 4.2-3.7 Ga. The MESSENGER spacecraft provided detailed geochemical data for surface rocks and revealed that Mercury is unusually enriched in sulfur compared to other terrestrial planets. The major element composition of these lavas also constrain melting conditions and residual mantle sources. Surface basalts were produced by 10 to 50% partial melting of variably enriched lherzolitic mantle sources. The average melting degree is lower for the young Northern Plains (0.27±0.04; 1410°C at 160 km) than for the older Heavily-cratered terranes (0.46±0.02; 1650°C at 360 km), indicating that melt productivity decreased with time. This evolution supports strong secular cooling of Mercury's mantle between 4.2 and 3.7 Ga and explains why very little magmatic activity occurred after 3.7 Ga. MESSENGER data are used to constrain the oxygen fugacity of Mercury's interior to IW-5.4±0.4 when the lavas were produced in the mantle. We also estimate that the mantle of Mercury most probably contains 7-11 wt.% S and that the metallic core has little sulfur (< 1.5 wt.% S). In addition to extreme surface temperatures, highly reducing conditions at the surface of Mercury do not offer adequate conditions for the development of life.

A SOLAR ESCALATOR ON MARS: SELF-LIFTING OF DUST LAYERS BY RADIATIVE HEATING

Frank Daerden and Lori Neary

Belgian Institute for Space Aeronomy

Dust layers detected in the atmosphere of Mars by the light detection and ranging (LIDAR) instrument on the Phoenix Mars mission are explained using an atmospheric general circulation model. The layers were traced back to observed dust storm activity near the edge of the north polar ice cap where simulated surface winds exceeded the threshold for dust lifting by saltation. Heating of the atmospheric dust by solar radiation caused buoyant instability and mixing across the top of the planetary boundary layer (PBL). Differential advection by wind shear created detached dust layers above the PBL that ascended due to radiative heating and arrived at the Phoenix site at heights corresponding to the LIDAR observations. This is the first time that detached layers of dust are successfully simulated in a global atmospheric model for Mars. The self-lifting of the dust layers is similar to the "solar escalator" mechanism for aerosol layers in the Earth's stratosphere.

Latest results from Rosetta

Johan De Keyser

Belgian Institute for Space Aeronomy

Comets typically reside in the most distant regions of our solar system. From time to time one of these objects, typically less than a few kilometers in diameter, is deflected towards the Sun. Near the Sun, the ice warms up and the gas and dust are released, creating an "atmosphere". The interaction of the atmosphere with the Sun produces the typical comet tails that can have huge dimensions. For years, our knowledge of comets was based on telescope observations and included spectroscopic analysis. After the first visit of a comet in 1986 by the European probe Giotto and after other NASA cometary probes, comet research is now booming due to the Rosetta spacecraft, which arrived near Comet 67P / Churyumov-Gerasimenko in August 2014, set down the Philae lander, and is offering us surprises ever since. The presentation will review the latest results, with an emphasis on the findings by the coma mass spectrometer in which Belgium plays an important role.

Artist impression of Rosetta and Philae at Comet 67P/C-G (not to scale). Credits: ESA/ATG medialab; Comet image: ESA/Rosetta/Navcam

Invited author:

During his doctoral thesis, J. De Keyser was strongly interested in scientific computing and fluid dynamics. After his doctorate, he started at the Institute for Space Aeronomy where he is Head of the Space Physics Division at present. He is captivated by the study of the solar wind and the magnetosphere, and is involved in several related ESA space missions such as the past "Ulysses" mission, the ongoing "Cluster" mission, and the PICASSO cubesat currently under construction. Today, his research focuses on the study of the cometary environment with the mass spectrometer ROSINA / DFMS on Rosetta, on which he is Co-Investigator.

PROTEROZOIC TIME CONSTRAINTS ON THE DEPOSIT OF THE MBUJI-MAYI SUPERGROUP,

DEMOCRATIC REPUBLIC OF CONGO (DRC)

C. FRANÇOIS[1], B. KABAMBA BALUDIKAY[1], J.Y. STORME[1], D. BAUDET[2], J.L. PAQUETTE[3] , M. Fialin[4] & E.J. JAVAUX[1]

[1]Palaeobiogeobiology-Palaeobotany-Palaeopalynology, University of Liège, Quartier Agora, Allée du 6 Août, 14, Bât. B-18. B-4000 Liège 1, Belgium. c.francois@ulg.ac.be; [2] Earth Sciences Department, Royal Museum for Central Africa, Tervuren, Belgium; [3] Laboratoire ''Magmas et Volcan'' (CNRS UMR 6524), Université B. Pascal, F-63 038 Clermont-Ferrand Cedex, France; [4] Camparis, Université Paris 6, 4 place Jussieu, 75252 Paris Cedex 5, France

The Sankuru-Mbuji-Mayi-Lomami-Lovoy (SMLL) Basin, DRC, located between the Archean-Paleoproterozoic Kasai Craton and the Mesoproterozoic Kibaran Belt, includes the Mbuji-Mayi Supergroup. This sedimentary sequence is unaffected by regional metamorphism and preserves a large diversity of well-preserved acritarchs (organic-walled microfossils), evidencing the diversification of complex life (early eukaryotes) for the first time in mid-Proterozoic redox stratified oceans of Central Africa (*Baludikay et al., submitted*).

Lithostratigraphically, this Supergroup is composed of two distinct successions (i) a lower siliciclastic sequence of BI Group (*ca.* 1175 Myr to *ca.* 882 Myr (*Delpomdor et al., 2013*) or *ca.* 1050 Myr (*Cahen et al., 1954 ; Holmes & Cahen, 1955*) unconformably overlying the *ca.* 3.0-2.6 Gyr granitoid Dibaya Complex to the North (*Delhal et al., 1976*); and (ii) a poorly constrained upper carbonate sequence with sparse shales of the BII Group. Basaltic pillow lavas overlying the Mbuji-Mayi Supergroup were dated around 950 Myr (*Cahen et al., 1974 ; Cahen et al., 1984*).

To better constraint the age of this Supergroup, we combine different geochronological methods, in particular on diagenetic minerals such as monazite (*Montel et al., 1996, Rasmussen & Muhling, 2007*) and xenotime (*McNaughton et al., 1999*) but also on zircons. For the BI Group, results of *in situ* U-Pb datings with LA-ICP-MS on monazite, xenotime and zircon (*Laboratoire Magmas et Volcans, Clermont-Ferrand*) provide ages between 2.9 and 1.2 Gyr for zircons and between 1.4 and 1.03 Gyr for monazites and xenotimes. New results of *in situ* U-Th-Pb datings of well-crystallized monazites and xenotimes with Electron MicroProbe (*Camparis, UPMC, Paris*), highlight that some crystals display zonations with an inherited core older than 1125 Myr and diagenetic rims around 1050-1075 Myr. This provides that the diagenesis of BI Group is younger than 1175 Myr (*Delpomdor et al., 2013*) and probably around 1050-1075 Myr (age on 2 syngenetic galenas (*Cahen et al., 1954 ; Holmes & Cahen, 1955*), and ages obtain on monazite and xenotimes rims in this study).

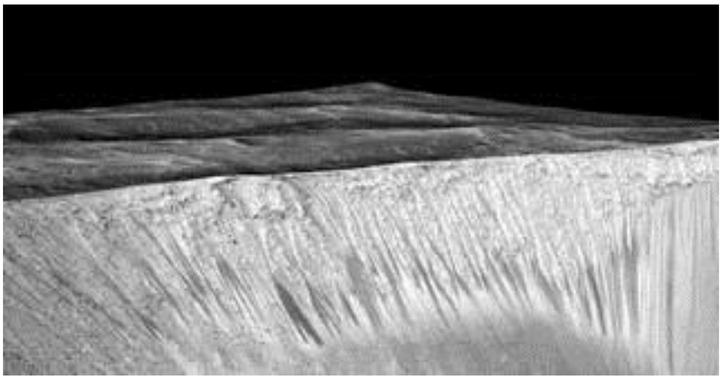
Sm-Nd datings on basaltic pillow lavas overlying the Mbuji-Mayi Supergroup (previously dated around 950 Myr (*Cahen et al., 1974; Cahen et al., 1984*) are in progress (Collaboration*: V. Debaille, Laboratoire G-Time, ULB, Bruxelles*) to precisely limit in time the end of diagenesis in this Supergroup.

WATER ON MARS

Nicolas Mangold

Université de Nantes

After the recent findings of hydrated minerals on slopes where streaks are seen by NASA's Mars Reconnaissance Orbiter (MRO), we have strong evidence that salt liquid water flows intermittently on present-day Mars. The hydrated salts would lower the freezing point of a liquid brine, just as salt on roads on Earth causes ice and snow to melt more rapidly.



Dark narrow streaks of a few hundred meters in length and called "recurring slope lineae" on Mars. Image from HIRISE (High Resolution Imaging Science Experiment). Credits: NASA/JPL/University of Arizona.

Search for water on Mars in the recent years has definitively settle the question about the existence of water on Mars by pointing out that rivers and large flows may have covered the surface in its early history. Billions of years ago, Mars was warmer and wetter than today, which could have supported microbial life in some regions if water was long lasting enough. The presentation will review the state of the art concerning the geology of Mars in relation to water.

The author:

Nicolas Mangold is a well-known planetary geologist, specialist of Mars geology. His activities aim to improve our understanding of the climate evolution of Mars, the role and abundance of water and its link with the geological evolution. Nicolas Mangold is heavily involved in space missions such as ESA Mars Express (Co-I OMEGA and HRSC) and NASA Mars Reconnaissance Orbiter (Co-I of HiRISE), Curiosity (Co-I ChemCam) and Rover2020 (Co-I of SuperCam).

EXPECTED PERFORMANCES OF THE NOMAD INSTRUMENT ONBOARD EXOMARS TGO.

Séverine Robert

Belgian Institute for Space Aeronomy

NOMAD (Nadir and Occultation for MArs Discovery) is one of the four instruments on board the ExoMars Trace Gas Orbiter, scheduled for launch in March 2016. It consists of a suite of three high-resolution spectrometers – SO (Solar Occultation), LNO (Limb, Nadir and Occultation) and UVIS (Ultraviolet and Visible Spectrometer). Based upon the characteristics of the channels and the values of Signal-to-Noise Ratio obtained from radiometric models discussed in [Vandaele et al., Optics Express, 2015] and [Thomas et al., Optics Express, 2015], the expected performances of the instrument in terms of sensitivity to detection have been investigated. The analysis led to the determination of detection limits for 18 molecules, namely CO, H_2O, HDO, C_2H_2, C_2H_4, C_2H_6, H_2CO, CH_4, SO_2, H_2S, HCl, HCN, HO_2, NH_3, N_2O, NO_2, OCS, O_3. NOMAD should have the ability to measure methane concentrations <25 parts per trillion (ppt) in solar occultation mode, and 11 parts per billion in nadir mode. Occultation detections as low as 10 ppt could be made if spectra are averaged [Drummond et al., Planetary Space and Science, 2011]. Results have been obtained for all three channels in nadir and in solar occultation.

PLANETARY EVOLUTION AND LIFE: ASTROBIOLOGY FROM A PLANETARY SCIENCE PERSPECTIVE

Tilman Spohn

DLR Institute of Planetary Research, Berlin, Germany

The habitability of planets has received increasing interest in recent years, in particular in view of the increasing number of detected extrasolar planets. Planetary habitability (for life as we know it) is usually thought to require water on (or near) the surface and a sufficient supply of energy and nutrients. The request for water on the surface leads to the concept of the habitable zone where stellar radiation and atmosphere green-housing keep the surface temperature within the stability range of liquid water. A magnetic field is argued to serve to protect an existing atmosphere against erosion by the stellar wind and thus to help stabilize the presence of water and habitability.

Present theories of the origin of life on Earth and an early chemotrophic biosphere require volcanic activity and the associated large thermal gradients as energy and entropy sources. Magnetic fields are generated in the cores of terrestrial planets and thus habitability is linked to the evolution of the interior through magnetic field generation and volcanic activity. Moreover, the interior is a potential source and sink for water and other greenhouse gases and may interact with the surface and atmosphere reservoirs through volcanic activity and recycling. The most efficient known mechanism for recycling is plate tectonics. On the Earth, surface water is stabilized by complex interactions between the atmosphere, the biosphere, the oceans, the crust, and the deep interior in the carbon-silicate cycle for which plate tectonics is a central element. But plate tectonics is widely believed to require water in the mantle to operate and it can thus be argued that plate tectonics is an element linking the biosphere to the evolution of the planet's interior.

Previous studies have proposed that life (together with plate tectonics) has caused a change in the redox-state of the mantle and provided a path for continent formation. We present numerical model that relates bioactivity and plate tectonics to the growth of the continental surface area of the Earth and to the hydration state of the mantle. The link is provided by assuming that bioactivity causes an increase in erosion of continental crust as compared to a putative abiotic Earth and an increase in the thickness of the sedimentary layer on top of a subducting oceanic slab. If the presence of life has increased continental weathering over time, as is widely believed, we conclude that Earth-like planets lacking life would have a dry mantle, may lack continents and possibly even plate tectonics altogether.

THE NOMAD INSTRUMENT ON-BOARD THE EXOMARS TRACE GAS ORBITER: CURRENT STATUS

Loïc Trompet(1), A.C. Vandaele(1), S. Robert(1), I. R. Thomas(1), A. Mahieux (1,2), V. Wilquet (1), F. Daerden(1), C. Depiesse(1), S. Berkenbosch (1), R. Clairquin (1), E. Neefs(1), B. Ristic(1), J.J. Lopez- Moreno(3), M. R. Patel(4), G. Bellucci(5) and the NOMAD team

(1) BIRA-IASB, Avenue Circulaire, Uccle, Brussels, Belgium; (2) FNRS, Brussels, Belgium
(3) IAA, Granada, Spain; (4) Open University, Milton Keynes, UK; (5) IAPS, Rome, Italy

The “Nadir and Occultation for MArs Discovery” (NOMAD) is a BIRA-IASB instrument that will be part of the ExoMars Trace Gas Orbiter launched in Mars 2016. This spectrometer has 3 channels to study the Martian atmosphere across a wide spectral range. The “Solar Occultation” (SO) channel is a copy of the SOIR instrument on board Venus Express and this previous instrument has made more than 1500 valid measurements. The second channel is the “Limb, Nadir and Occultation” (LNO) spectrometer, an improved version of SOIR more sensitive to lower light levels for nadir observations. The last spectrometer is the “Ultraviolet-VISible” (UVIS) channel which is dedicated to the detection of ozone and aerosols. It operates in nadir and solar occultation modes. The PFM and FS models of the instrument successfully passed all tests and the PFM has already been integrated onto the spacecraft.

The main purpose of NOMAD is to better characterize the atmosphere of Mars by the detection of a wide range of trace gases (such as CO, CO_2, H_2O, HO_2, NO_2, N_2O, C_2H_2, C_2H_4, C_2H_6, H_2CO, CH_4, HCN, OCS, SO_2, H_2S, HCl and O_3), by the characterization of their spatial and temporal distribution, and by the localization of source and sink regions (e.g. (photo-)chemical processes and processes related to dust and/or ice, region of surface volcanism/outgassing). To achieve this goal, the spectral resolution of NOMAD surpass those of previous surveys of Mars by an order of magnitude. NOMAD will also extend the monitoring of Mars climatology and seasonal cycles that successive space missions started in the past decades.