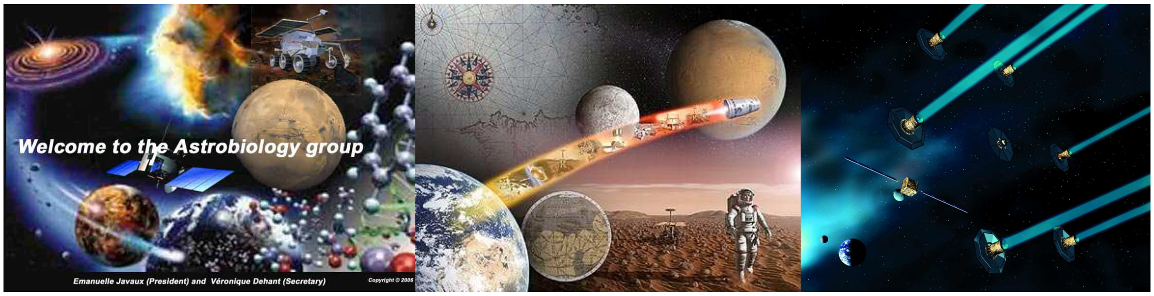

The FNRS contact group "Astrobiology"

has the pleasure to invite you to its
first official Workshop

"ASTROBIOLOGY AND HABITABILITY"
June 12th 2007

Belgian Royal Academy of Sciences

Plenary speakers
Dr Agustin Chicarro, ESA Mars Express Project Scientist
"Latest scientific results of the Mars-Express Mission"
Dr Frank Selsis, Ecole Normale Supérieure de Lyon,
"Habitable exoplanets"

Organization:
E. Javaux, V . Dehant, & Ph. Claeys
Abstract submission and workshop program at
http://astrobio.oma.be/

Astrobiology workshop 2007: "Astrobiology and habitability"

Date: June 12th, 10H00 to 16H00.
Location: the Belgium Royal Academy of Sciences, rue Ducale, BXL., room "Prigogine". The place is next to the Royal palace, easily reached by foot from the central train station (http://www.
Lunch: sandwiches at the patio

Speakers
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PROGRAM

10:00-10:15 Véronique Dehant & Emmanuelle Javaux the FNRS contact group and astrobiology

<u>Morning session: habitability in the solar system</u> Chair: ?

10:15-11:00 Agustin Chicarro (ESA Mars Express Project Scientist)
Plenary talk "Latest scientific results of the Mars-Express Mission"

11:00-11:30 coffee break

11:30-11:45 C. Muller (1), M.R. Patel (2), J.C. Zarnecki (2), C. Depiesse (1), D. Moreau (1), D. Gillotay (1), M.R. Leese (2), C.S. Cockell and M.C. Towner (2). The UV-VIS spectrometer for the ExoMars mission: Objectives and operations.

11:45-12:00 O.Karatekin , Le Binh San Pham, V.Dehant, H.Hammer
Toward a climatological model for Mars

12:00-12:15 S.Goderis, Ph.Claeys How to use platinum group elements (PGEs) to determine the nature of the projectiles (=the meteorites) responsible for the formation of terrestrial impact structures?

12:15-12:30 Elie Verleyen, Dominic A. Hodgson, Koen Sabbe, Annick Wilmotte, Arnaud Taton, Sylvie Cousin, Aaike De Wever, and Wim Vyverman
Biodiversity Assessments Of Lacustrine Microbial Communities In Antarctic Lakes

12:30-12:45 Namsaraev Z.B. Namsaraev B.B. Microbiological and ecological features of Siberian soda lakes

12:45-14:00 lunch

<u>Afternoon session: habitability of Exoplanets</u> ***Chair:?***

14:00-14:45 Dr Frank Selsis (Ecole Normale Supérieure de Lyon)
Plenary talk "Habitable exoplanets"

14:45-15:00 Sven De Rijcke The influence of Galactic chemical evolution on the habitability of terrestrial planets

15:00-15:15 D. Pourbaix, C. Siopis, G. Sadowski, B. Tingley, and A. Jorissen What Gaia can do you.

15:15-15:30 D Mawet? Surdej?

15:30-16:00 discussion around coffee break

16:00 end of workshop

Abstracts (by alphabetical order)

Microbiological and ecological features of Siberian soda lakes

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Siberian soda lakes are exceptional biotopes, subjected to extreme seasonal fluctuations of temperatures and salinities. In the South Siberian region the climate is semiarid; temperature ranges from -40 during winter up to +40ºC in summer. In contrast to Africa and Antarctica, Siberian lakes have a relatively unstable water regiment with fluctuations of the water salinity from several grams per liter up to saturation. During the harsh autumn-winter conditions the water of Siberian lakes freeze-out with concomitant precipitation of dissolved salts and the remaining water are covered by the layer of ice. This process attracts attention as a modern analogue of freezing out of episodic lake formations on Mars. During summer droughts the water evaporates with the precipitation of carbonates, sulfates of sodium and magnesium, and finally halite. The pH of water during year fluctuates from alkaline at low salinities to neutral at the final stages of evaporation/freezing.

Our studies showed that, despite the extreme conditions, active microbial communities dominated by alkaliphilic trichomic cyanobacteria and anoxygenic phototrophic bacteria are functioning in these lakes. In some of the studied lakes thick cyanobacterial mat is formed. Primary production (photo and chemosynthesis) dominates over destruction processes at low and moderate salinities. But during winter freezing or summer evaporation of lakes the destruction processes dominates over production of organic matter. Low rates of microbial destruction processes were observed even at the temperature -8ºC in the water remaining under the ice. During autumn and winter organic matter concentration gradually decreases for 80% due to activity of heterotrophic bacteria.

The influence of Galactic chemical evolution on the habitability of terrestrial planets

Author : Sven De Rijcke (*Universiteit Gent*)

Processes at the galactic scale influence planet formation and affect the habitability of terrestial planets (Gonzalez 2001, Icarus, 152, 185; Lineweaver et al. 2004, Science, Vol. 303, 59). Successive generations of stars need to have to raised the elemental abundances to a sufficiently high level for earth-like planets to be able to form. In order to sustain plate tectonics, a terrestial planet needs to contain sufficient amounts of radio-active elements, such as 238U and 40K, that produce the necessary heat. On the other hand, stars with higher metallicity are more likely to harbour a massive Jupiter-like planet that, by migrating inwards, may eject terrestial planets from the habitable zone (Ward 1997, Icarus, 126, 261). Also, conditions in the galactic neighborhood of a planet need to be sufficiently benign : frequent nearby supernova-explosions, for example, are not favorable because they deplete a planet's ozone layer (Gehrels et al. 2003, Astrophys. J., 585, 1169).

All these processes are related to the Galaxy's chemical evolution and, by their very nature, are place and time dependent. This has given rise to the notion of a Galactic Habitable Zone, or GHZ, in which habitable terrestial planets are most likely to form. I have constructed a chemical evolution model that accurately reproduces the wealth of data available for the Milky Way. With this model, I can reconstruct the Milky Way's chemical evolution and constrain the spatio-temporal variation of its GHZ. The effects of metallicity and supernova explosions on the formation and habitability of terrestial planets are self-consistently taken into account. Making assumptions about the time it takes for life to form and to go extinct, I derive a space and time dependent analog of the famous Drake equation for the surface mass density of stars with habitable planets in the Milky Way disk.

BIODIVERSITY ASSESSMENTS OF LACUSTRINE MICROBIAL COMMUNITIES IN ANTARCTIC LAKES

Aurors: Elie Verleyen[1,*], Dominic A. Hodgson[2], Koen Sabbe[1], Annick Wilmotte[3], Arnaud Taton[3], Sylvie Cousin[1], Aaike De Wever[1], and Wim Vyverman[1]

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Parts of Antarctica have recently witnessed one of the most rapid temperature excursions on Earth that already had a detectable impact on the cryosphere and affected lacustrine ecosystem functioning. In order to predict the effects of future climate changes on the microbial organisms inhabiting the lakes in the sparse ice-free oases, we not only need better baseline information on their biodiversity, but also on the climate related environmental factors structuring these communities. Here we used different approaches to study the biodiversity of microbiota, namely microscopy-based taxonomic inventories of diatom floras, high performance liquid chromatography of photosynthetic pigments to study the autotrophic community structure, and a culture independent molecular fingerprinting technique (denaturant gel electrophoresis (DGGE) of the SSU rDNA) to asses the genetic composition and distribution of cyanobacteria and eukaryotes in microbial mat samples from east Antarctic lakes. The dataset covers a wide limnological gradient across five different ice-free oases and contains the most abundant lake types when classified according to mixing regime, lake origin, and age. Sequence analysis of selected DGGE bands revealed the presence of a large amount of protists (alveolates, stramenopiles, and green algae), fungi, tardigrades and nematodes and many representatives of *Leptolynbya* and *Nostoc* among the cyanobacteria, which corroborates our and previous microscopy-based observations and pigment based inventories. Although this survey is far from complete, our results indicate that each oasis is different in terms of microbial community structure. Multivariate and variation partitioning analyses revealed that the microbial mat community structure is regulated by both spatial (i.e., dispersal and migration) and limnological factors of which salinity (and related variables), lake water depth and nutrient concentrations are of major importance. As these three groups of predictors were shown to change drastically in response to variations in air temperature in Antarctica, further efforts should be devoted to the

protection of these often endemic organisms and their unique habitats, and to better asses their current biodiversity patterns using state-of-the art molecular techniques. In addition, the study of microorganisms adapted to these extreme conditions (i.e., low temperature and high UV) and the traces they leave in the sedimentary record are of relevance for research regarding life on early Earth, Mars, and astrobiology in general.

What Gaia can do you.

Autors: D. Pourbaix, C. Siopis, G. Sadowski, B. Tingley, and A. Jorissen

The ESA Cornerstone Mission Gaia will survey the whole sky from 2012 on for a period of five years. Gaia will combine unprecedented astrometric capa- bilities with radial velocity measurements and very accurate multi-band photometry. Its astrometry and photometry make Gaia a unique tool for astrobiology with a few thousands exoplanets that, according to current simulations, should be detected and characterised (orbit, host star, ...).

The Institute of Astronomy and Astrophysics (IAA) of ULB plays a key role in the astrometric detection of extrasolar planets and, to a lesser extent, in their photometric detection too. The Data Processing and Analysis Con- sortium, responsible for the design and implementation of the data reduc- tion pipeline, is subdivided into Coordination Units. The manager of the CU in charge of the chunk of the pipeline dealing with non-single stars is D. Pourbaix from IAA. He is also responsible for the code for astrometric orbit fitting of non-single stars. Based on the current estimates, that code will detect and characterise the orbit of a few thousands single extra-solar planets. Though less likely to be detected due to the number of observations, other codes will deal with planetary systems around nearby stars.

The UV-VIS spectrometer for the ExoMars mission: Objectives and operations.

Autors: C. Muller (1), M.R. Patel (2), J.C. Zarnecki (2), C. Depiesse (1), D. Moreau (1), D. Gillotay (1), M.R. Leese (2), C.S. Cockell and M.C. Towner (2).

(1) *Belgian Institute for Space Aeronomy, Belgium*
(2) *Planetary and Space Sciences Research Institute, the Open University, Milton Keynes, U.K.*

The ExoMars scientific payload is optimised to search for biomarkers and potential astrobiological habitats in the Martian near-surface environment. The UV-VIS spectrometer (UVIS) is designed to determine for the first time the magnitude of the UV flux reaching the Mars surface in the ranges of UV-C (190-280nm) and UV-B (280-315nm) that in general have a deleterious impact on most carbon-based organic structures.
Also, intense short wavelength UV can lead to the production of oxidizing radicals that could affect the potential for extant life to persist. Great uncertainty lies in the derivation of optical properties of suspended dust in the Martian atmosphere for UV wavelengths - little agreement has been reached to date, due to the lack of detailed spectroscopic investigation, and these parameters are required for accurate modelling of the transfer of UV to the surface in

astrobiological investigations. This instrument will provide surface spectra ranging from the UV to visible, thus allowing the derivation of optical properties across a wide region of wavelength and simultaneous cross-comparison with many previous observations in the visible region of the spectrum. UVIS is an extremely compact spectrometer, and is currently in development through ESA to miniaturise and raise technology development in time for the ExoMars mission. UVIS will monitor the local solar irradiance at the Mars surface at high resolution (1-2 nm) throughout the UV and visible spectrum (200-650 nm), with a mass requirement of <300g. The spectrometer utilises a 1024 element linear photodiode array, with a Czerny-Turner optical bench with a focal length of only 75 mm, all contained within an extremely small enclosure, and will be ruggedised to withstand the extreme environmental conditions of spaceflight. Presented here are initial results from laboratory experiments, verifying the concept of the spectrometer for its development for the ExoMars mission to Mars. Studies of the present UV penetration based on Mars-Express SPICAM results will also be shown.

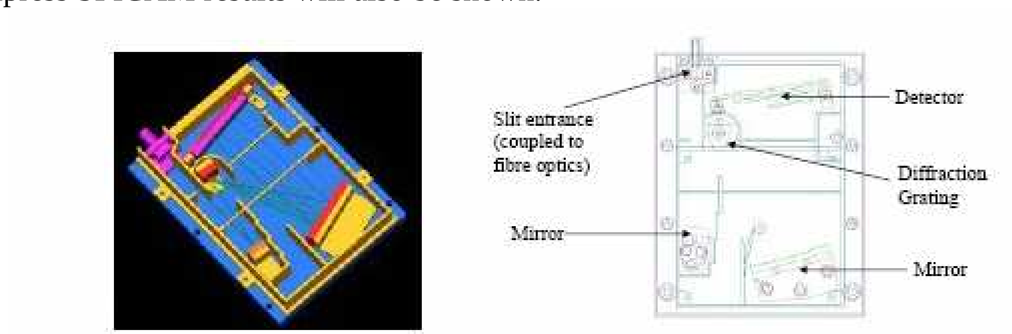

Fig.1: current schematics of the instrument.

How to use platinum group elements (PGEs) to determine the nature of the projectiles (=the meteorites) responsible for the formation of terrestrial impact structures?

Autor: S. Goderis[1*], Ph. Claeys[2]

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Interplanetary bodies such as comets and asteroids are responsible for the formation of impact craters on all solid bodies of the solar system. Intact impactor fragments are rarely found in the vicinity of terrestrial impact craters due to complete vaporization during impact supplemented by weathering and erosion, thus complicating the identification of the impactor. However, during crater formation a small amount of meteoritic material (vapor and/or melt) is incorporated into the crater lithologies (=impactites), resulting in a measurable geochemical signal in these molten or shocked rocks that differs from the signature measured in terrestrial rocks. This signal can be used to confirm the origin of the structure and can, in some cases, even help to determine the precise nature of the crater-forming object. Three major geochemical methods are capable of measuring very small amounts of meteoritic material (in most craters this amount does not exceed 1 wt.% bulk meteoritic material). The use of osmium (Os) and chromium (Cr) isotopic ratios, and siderophile element ratios [platinum group elements (PGEs), nickel (Ni), cobalt (Co), and chromium (Cr)] - alone or combined – has already successfully resulted in the determination of the projectile-type of approximately 25 of the ~174 impact structures, recognized on Earth today [1, 2, 3]. A comparative review of the procedures and techniques of these 3 methods has recently been published, comparing their advantages and limitations [3]. Osmium isotopic ratios are currently only suitable for the detection, but not the precise identification of an impactor component. Chromium isotopes require the largest projectile contribution to detect an extraterrestrial component (several wt.%), and this method only discriminates between carbonaceous chondrites, enstatite chondrites, and all other types of meteorites. For the moment, we thus prefer to use PGEs, capable of identifying even minute ~ 0.2 wt.% proportions of a chondritic projectile in an PGE rich target [3]. Osmium, iridium, ruthenium, platinum, rhodium, and palladium are the 6 platinum group elements - on Earth concentrated in the core due to differentiation in an early phase of the Earth's evolution [4]. Their strong siderophile properties result in a significant enrichment in meteorites compared to the Earth's crust. Elevated PGE concentrations, in combination with higher values for the other siderophile elements (e.g. Ni, Co and partially lithophile Cr), may thus reveal the presence of a meteoritic component in crater lithologies [2, 3, 5, 6, 7]. Recent studies have shown that the use of their specific inter-elemental ratios, which can be derived from the slope of the mixing line of two PGEs, enables the determination of the PGE element ratios of the original projectiles without having to consider the indigenous component [3, 8, 9, 10]. Comparison of these projectile ratios with the elemental ratios in the different types of meteorites (e.g., chondrites) renders possible a precise projectile identification. This comparative approach relies on an extensive database of the PGE compositions of different types of meteorites. The methodology has been described in details [10]. The application of this method has allowed a satisfactory projectile identification (with high degree of confidence) for a number of impact craters, with for example an L- or LL-chondrite for the Morokweng crater (South Africa), an L-chondrite in the case of the Popigai (Siberia) and Wanapitei (Canada) craters, non-magmatic iron meteorites for the Rochechouart and Sääksjärvi impact structures, and an LL-chondrite for the Serenitatis Basin on the Moon (Apollo 17 samples) [e.g., 9, 10, 11].

Using the example of the Gardnos crater, a well-exposed late Precambrian impact structure in Norway, we will demonstrate the procedure described above with the detection of an non-magmatic iron meteoritic signature for the Gardnos impactor as a result. Non-magmatic iron meteorite (NMI), in this case a IA or IIIC, are characterized by a complex formation history (e.g., partial fractionation) and contain a large amount of silicate inclusions. Some of these silicate inclusions, found inside the metal phase of NMI, are almost chondritic in composition. This implies that the asteroid, of which a fragment caused the formation of the Gardnos crater, was composed of both a metallic phase and a Cr-rich silicate phase.

Acknowledgement: Thanks to the Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT-Vlaanderen).

Ref: [1] Earth Impact Database (2007) *http://www.unb.ca/passc/ImpactDatabase/*. [2] Koeberl (1998) Geol. Soc. Spec. Publ. **140**, 133–153. [3] Tagle & Hecht (2006) MAPS **41(11)**, 1721-1735. [4] McDonough & Sun (1995) Chem. Geol. **120**, 223-253. [5] Kyte et al. (2004) LPI **35**, 1824 (abstract). [6] Palme H (1982) GSA Spec. Pap., 190. [7] Wolf et al. (1980) GCA **44**, 1015-1022. [8] McDonald (2002) MAPS **37**, 459-464. [9] McDonald et al. (2001) GCA **65**, 299-309. [10] Tagle & Claeys (2005) GCA **69**, 2877-2889. [11] Tagle et al. (2007) MAPS (*submitted*).

MARS EXPRESS – GEOLOGICAL EVOLUTION AS A CLUE TO ASTROBIOLOGY

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The ESA Mars Express mission, launched on 02 June 2003 from Baikonur, Kazakhstan, onboard a Russian Soyuz rocket, includes an orbiter spacecraft which was placed in a polar martian orbit. In addition to global studies of the surface, subsurface and atmosphere of Mars, with an unprecedented spatial and spectral resolution, the unifying theme of the mission is the search for water in its various states everywhere on the planet by all instruments using different techniques. A summary of scientific results from all experiments after more than three terrestrial years in orbit is given below.

The High-Resolution Stereo Colour Imager (HRSC) has shown breathtaking views of the planet from both hemispheres, pointing to very young ages for both glacial and volcanic processes, from hundreds of thousands to a few million years old, respectively. The IR Mineralogical Mapping Spectrometer (OMEGA) has provided unprecedented maps of H_2O ice and CO_2 ice in the polar regions, and determined that the alteration products (phyllosilicates) in the early history of Mars correspond to abundant liquid water, while the post-Noachian products (sulfates and iron oxides) suggest a colder, drier planet with only episodic water on the surface. The Planetary Fourier Spectrometer (PFS) has confirmed the presence of methane for the first time, which would indicate current volcanic activity and/or biological processes. The UV and IR Atmospheric Spectrometer (SPICAM) has provided the first complete vertical profile of CO_2 density and temperature, and has discovered the existence of nightglow, as well as that of auroras over mid-latitude regions with paleomagnetic signatures and very high-altitude CO_2 clouds. The Energetic Neutral Atoms Analyser (ASPERA) has identified solar wind scavenging of the upper atmosphere down to 270 km altitude as one of the main culprits of atmospheric degassing and determine the current rate of atmospheric escape. The Radio Science Experiment (MaRS) has studied the surface roughness by pointing the spacecraft high-gain antenna to the Martian surface. Also, the martian interior has been probed by studying the gravity anomalies affecting the orbit, and a transient ionospheric layer due to meteors burning in the atmosphere, was identified by MaRS. Finally, results of the subsurface sounding radar (MARSIS) following the late deployment of its antennas due to safety concerns, indicate strong echoes coming from the surface and the subsurface allowing to identify buried impact craters and tectonic structures, as well as the very fine structure of the polar caps. The Northern crust appears thus just as old as the Southern one, owing to the large number of impact basins being recognized. Also, probing of the ionosphere reveals a variety of echoes originating in areas of remnant magnetism.

Mars Express is already hinting at a quantum leap in our understanding of the planet's geological evolution, to be complemented by the ground truth being provided by the American MER rovers. The nominal mission lifetime of one Martian year for the orbiter spacecraft has already been extended by another Martian year (687 days). During the extended mission, priority is being given to fulfill the remaining goals of the nominal mission (e.g., gravity measurements and seasonal coverage), to catch up with delayed MARSIS measurements during the nominal mission, to complete global coverage of high-resolution imaging and spectroscopy, as well as subsurface sounding with the radar, to observe atmospheric and variable phenomena, and to revisit areas where discoveries were made. Also, an effort to enlarge the scope of existing cooperation is being made, in particular with respect to other missions at Mars (such as MER and MRO) and also missions to other planets carrying the same instruments as Mars Express (i.e. Venus Express). Finally, Mars Express is providing valuable data for the preparation of ESA's Aurora Exploration Programme first mission to Mars (called ExoMars and including a capable rover to perform astrobiological, geophysical and climatological investigations), in terms of helping identifying potential landing sites on Mars, establishing a useful surface/subsurface geological database, as well refining the existing atmospheric one, in order to assess potential risks for the exploration of Mars. For further details on the Mars Express mission and its science results: **http://sci.esa.int/marsexpress/**

Toward a climatological model for Mars

O. Karatekin, Le Binh San Pham, V. Dehant, H. Lammer

Early in its history, Mars probably had a denser atmosphere which might have provided conditions favorable for the presence of liquid water on the surface, an essential prerequisite for the beginning of life and its further evolution. The rate of loss of the atmosphere depends on the efficiency of the atmospheric escape mechanisms. We examine the mechanisms which may have caused rapid erosion of an early Martian atmosphere and calculate the temperatures on the surface with the help of a surface energy balance model taking into account the solar insolation as a function of Martian obliquity changes as well green-house effects. The loss of the planetary magnetic field and large-scale impacts could have significant effects on atmospheric evolution by leaving the upper atmosphere unprotected to the solar XUV and EUV radiation and by radially accelerating outward the atmospheric particles above the escape velocity, respectively.

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