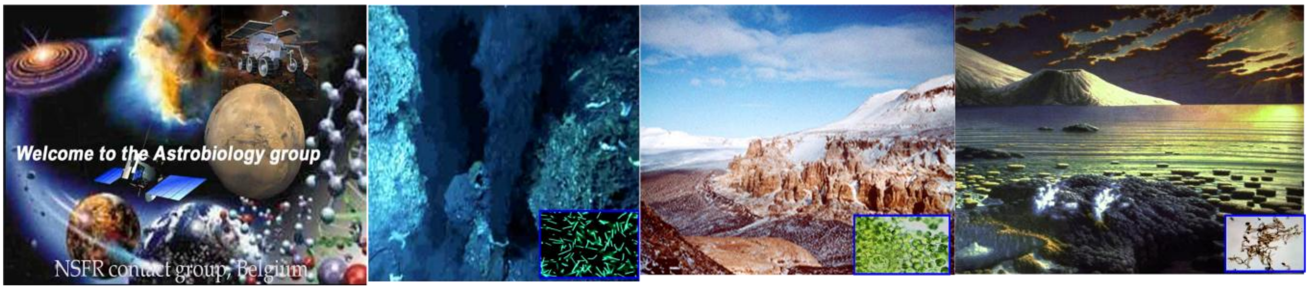


THE FNRS/NFSR "ASTROBIOLOGY: FROM STARS AND PLANETS TO EXTREME LIFE" CONTACT GROUP ANNUAL WORKSHOP

February 14th (10:00-17:00)
"Salle Méridienne"of the Royal Observatory of Belgium
rue circulaire/Ringlaan, 3, Brussels

Invited Speaker

Dr Alessandro Morbidelli (Nice Observatory)
Evolution of the Solar System

Followed by

Conference by Véronique Dehant (18:00)
Royal Academy of Sciences, 1, rue ducale, Brussels, Room Albert II
« Y-a-t-il d'autres planètes ou lunes habitables dans notre système solaire ? »

Organization: V. Dehant (ORB) & E. Javaux (ULg)
with the support of the FNRS, ULg & ORB
(contact: ej.javaux@ulg.ac.be); Details at http://astrobio.oma.be/

Program

	Speakers	Affiliation	Talks
10h00-10h30	**E Javaux-V Dehant**	FNRS Contact group	**Welcome coffee**
SOLAR SYSTEM			
10h30-11h00	**Veronique Dehant & the IAP team members**	ORB/UCL, VUB, ULB, ULg, DLR BISA, UGent	Planet TOPPERS IUAP
11h00-11h20	**Christian Muller**	IASB/BUSOC	The sun, its variations and life on the planets
11h20-11h40	**Rachelle Drummond, A.C. Vandaele, and F. Daerden**	BISA	NOMAD and the detection of methane
11h40-12h00	**Emmanuel Jehin**	ULg	Isotopic ratios in comets: New insights about the origin of water on Earth?
12h00-12h20	**Dagmar Obbels et al**	ULg	Metacommunity dynamics in Antarctic microbial organisms
12h20-12h40	**Ozgur Karatekin**	ORB	
12h40-14h00	**LUNCH**		
EXOPLANETS			
14h00-14h20	**Michaël Gillon**	ULg	The TRAPPIST exoplanet program
14h20-14h40	**De Saedeleer, Bernard**	UCL	How the incident flux from a star paces the paleoclimate on his planets? Possible extensions of the terrestrial case.
14h40-15h00	**Anne-Sophie Libert**	FUNDP	A 3-D dynamical study of the habitable zones of extrasolar planetary systems
15h00-15h40	***COFFEE BREAK***		
15h40-16h40	**INVITED TALK Allessandro Morbidelli**	NICE OBSERVATORY, FRANCE	Evolution of the Solar System
16h40-17h00	**GENERAL DISCUSSION**		
ROYAL ACADEMY OF SCIENCES			
18h00	**Véronique Dehant**	ORB	Y-a-t-il d'autres planètes ou lunes habitables dans notre système solaire ?

Abstracts
(by order of presentation)

PLANET TOPERS
Planets: Tracing the Transfer, Origin, Preservation, and Evolution of their ReservoirS
A proposed Interuniversity Attraction Pole (IAP)

Dehant Véronique (Royal Observatory of Belgium),
In alphabetic order:
Breuer Doris (Deutsche Zentrum für Luft- und Raumfahrt, Berlin)
Claeys Philippe(Vrije Universiteit Brussel),
Debaille Vinciane (Université Libre de Bruxelles),
De Keyser Johan (Belgian Institute for Space Aeronomy),
Javaux Emmanuelle (Université de Liège),
Goderis Steven (Vrije Universiteit Brussel),
Karatekin Özgur (Royal Observatory of Belgium),
Spohn Tilman (Deutsche Zentrum für Luft- und Raumfahrt, Berlin)
Vandaele Ann Carine (Belgian Institute for Space Aeronomy),
Vanhaecke Frank (Universiteit Gent),
Van Hoolst Tim (Royal Observatory of Belgium),
Wilquet Valérie (Belgian Institute for Space Aeronomy)

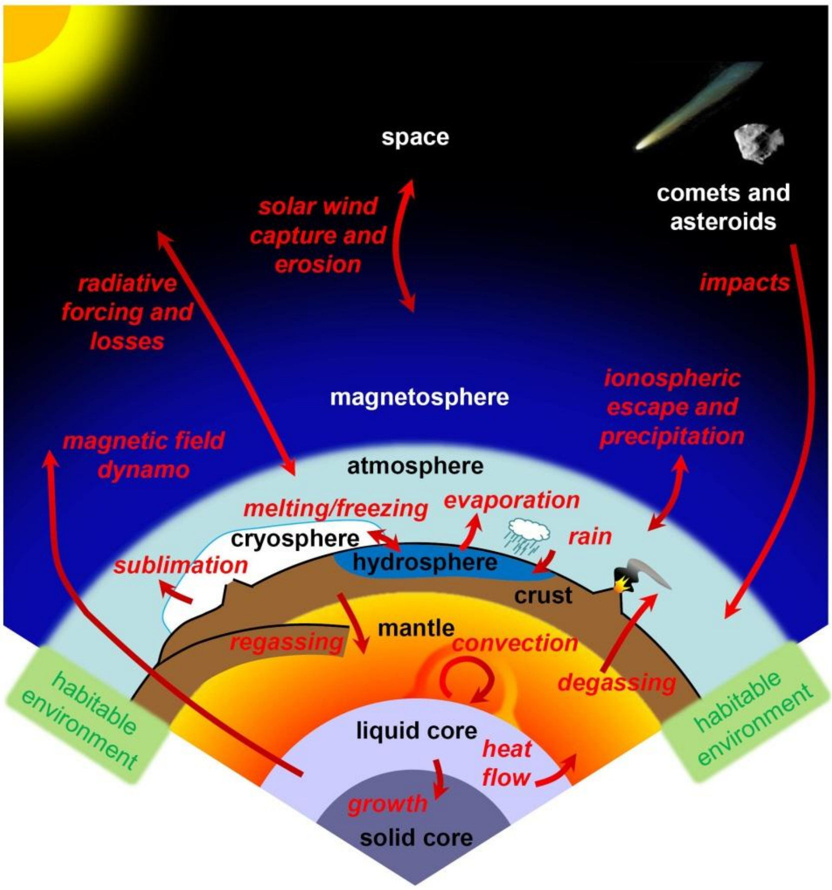
The evolution of planets is driven by the composition, structure, and thermal state of their internal core, mantle, lithosphere, crust, and by interactions with possible ocean and atmosphere. This proposal addresses the fundamental understanding of the relationships and interactions between those different planetary reservoirs and their evolution through time. It brings further insight into the origin and sustainability of life on planets, including Earth.
The proposed interdisciplinary approach applied in this project goes beyond that of current studies in Earth-System and Planetary Sciences and/or Astronomy by

- Encompassing the entire planet from the upper atmosphere to the deep interior in the frame of the study of its habitability;
- Including, beside the Earth, a whole range of rocky bodies in the Solar System: such as Earth-like planets, natural satellites, and undifferentiated asteroids.

Particular attention is devoted to Mars, but also to planets and satellites possessing an atmosphere (Earth, Mars, Venus and Titan) or a subsurface ocean (e.g., Europa), because those are the best candidates for hosting life.

The Interuniversity Attraction Pole (IAP) 'PLANET TOPERS' (Planets: Tracing the Transfer, Origin, Preservation, and Evolution of their ReservoirS) addresses four main themes: (1) the interaction between the interior and the atmosphere, (2) the interaction between the atmosphere and space, (3) the identification of preserved life tracers and interaction of life with planetary evolution, and (4) accretion and evolution of planets. The four themes are integrated into a comparative history of habitability conditions for Mars, Earth, and Venus.

The research program builds on, refines, and couples models of the individual reservoirs developed by the different partners. It also integrates new results of planetary geodesy – probing the deep interior, and of atmosphere remote sensing, laboratory studies of meteorite samples, and observations of traces of life in past and present extreme conditions. The search for biomarkers and traces of life on early Earth serves as a case study to refine techniques allowing to detect potential habitats and possible life on other planets. A strong emphasis is also placed on impact processes, an obvious shaper of planetary evolution, and on meteorites that document the early Solar System evolution and witness the geological processes taking place on other planetary bodies. The proposed research also relies on spectroscopic and isotopic laboratory measurements, geochemical analytical developments, and theoretical calculations to determine reference parameters and to unravel reaction mechanisms, allowing the optimal retrieval of information from observation data, and providing a deeper insight into the chemistry, physics, and dynamics of atmospheres and rocky materials.



Sketch with all the interactions between the reservoirs as foreseen in this project.

The research to be carried out by the IAP is organized as follows:

A) GOAL: to better understand the concept of habitability, i.e. the environmental conditions capable of sustaining life.

B) OBJECTIVES:

- To improve our understanding of the thermal and compositional evolution of the different reservoirs (core, mantle, crust, atmosphere, hydrosphere, cryosphere, (and space)) considering interactions and feedback mechanisms;
- To investigate the chronology of differentiation processes, the onset conditions of plate tectonics and recycling of the crust and their implications for the early thermal and compositional evolution of a planet;
- To examine the role of impacts of meteorites and comets in the atmospheric evolution of the planets, providing loss and replenishment of the atmosphere or possibly even changing the magnetic field;
- To determine the observational constraints related to meteorites, in order to better understand the impact process and impact fluxes as a function of time;
- To identify preserved biosignature and to understand the interactions through time between life and geochemical reservoirs; to search for traces of life, with early Earth as a case study;
- To perform a detailed comparison of the habitability of Mars, Earth, and Venus, based on the integrated analysis of the interacting reservoirs.

C) METHODOLOGIES:

- Remote sensing: analyzing and interpreting data recorded by existing instruments (space-based and ground-based), using improved models, such as radiative models of planetary atmospheres or thermal and compositional models of planetary interiors;
- In situ measurements: examining tracers of life in early Earth material (biosignatures) and extraterrestrial samples (meteorites), measurement of fields and particles in space from existing and future missions;
- Performing laboratory measurements and developing analytical and theoretical methods in support of such data;
- Developing and improving models and incorporating new results from laboratory data or spacecraft observations.

Of prime interest in terms of global system evolution are the early states of Mars, Venus, and Earth. Though the conditions on these planets were similar soon after their formation, their histories have diverged about 4 billion years ago. The reasons for this decoupling in evolution is addressed through comparative studies with other rocky bodies that from the start followed a different evolutionary pathway, such as Mercury, the moons or the small rocky bodies in the asteroid belt.

The IAP network involves teams combining different but highly complementary expertise. The partners belong to two Belgian federal institutions, four Belgian universities and one German Research Center. The Pole gathers existing and internationally recognized expertise in planetary sciences, geobiology, cosmo/geochemistry, and analytical and physical chemistry, with the aim of establishing a solid interdisciplinary network infrastructure in Belgium. Through this synergy, it enables the most advanced research in planetary evolution to be carried out and reinforces the international competitiveness of the Belgian teams involved. Backbone activities of the IAP include PhD student and post-doc training, working groups, PLANET TOPERS weeks, and public outreach activities. All these activities will further be strengthened by soft skill exchange and communication that focus on optimizing the interactions between the participating scientists.

As the research strategy mainly focuses on unraveling and understanding the mechanisms and exchanges between the various planetary reservoirs, specific methods will be developed to boost internal collaborations, e.g. by putting the emphasis, through the definition of PhD and Postdoctoral research topics, on the interaction between the different reservoirs, in a trans-disciplinary approach between teams. In cooperation and full synergy with the foreign partner, the goal is to evolve into an excellence center in planetology, astrobiology and habitability at the international level.

Determining the possibility and limitations of extraterrestrial life is of fundamental importance to mankind with profound philosophical implications. By evaluating the interactions between planetary evolution and life on such a large scale, the PLANET TOPERS project puts the evolution of our home planet (even the current anthropogenic effects) into perspective.

THE SUN, ITS VARIATIONS AND LIFE ON THE PLANETS.

Christian Muller
Belgian Institute for Space Aeronomy: IASB

The early Sun was very different in the beginning of planetary evolution to the point of making the Earth a different planet; however, the early Earth could support life. The explanations of the current literature will be presented together with the role of solar evolution on atmosphere and ocean evolution in terms of compatibility with surface life. In a more contemporary Earth, the Sun, which was thought not so long ago to be stable to the point that its total output was considered to be constant, shows variability with possible effects on climate and of course on life adaptation. These effects will be detailed as well as some examples of living system mitigation of solar variations negative effects. The consequences of this Sun driven space climate on habitability in the solar system will be exposed with emphasis on the terrestrial planets.

NOMAD AND THE DETECTION OF METHANE

Rachelle Drummond , Ann-Carine Vandaele, and Frank Daerden
Belgian Institute for Space Aeronomy: IASB/BISA

NOMAD is a flexible IR and UV-VIS spectrometer that can perform solar occultation, limb and nadir measurements. It has been accepted on the ExoMars Trace Gas Orbiter 2016. It's capacity to detect, profile and map methane and other trace gases that could indicate the presence of life on Mars, or point to previous life will be presented. This will be placed in the context of other gases, including CO2, CO, O3 and water vapour over the period of at least one Martian year.

ISOTOPIC RATIOS IN COMETS: NEW INSIGHTS ABOUT THE ORIGIN OF WATER ON EARTH?

Emmanuel Jehin
Institut d'Astrophysique et de Géophysique, Université de Liège

Isotopic abundance ratios are excellently suited to probe the origin of solar system matter. Knowledge of these ratios is particularly relevant for small solar system bodies, as these were much less altered since their formation than the planets and their satellites. Particularly comets are believed to have preserved unprocessed material of the solar nebula from the time of formation of the solar system. We will review the measurements of the isotopic ratios of the light elements (D/H, 12C/13C, 16O/18O, 14N/15N) in cometary dust and gas and discuss briefly their implications. Special emphasis will be put on the determinations and progresses performed in the field over the past years thanks to high resolution spectroscopy of the gaseous cometary comae obtained with the ESO Very Large Telescope by our team. The new measurement of D/H in comet 103P/Hartley2 with the IR Herschel satellite will be presented and its implication to the origin of water on Earth, discussed.

METACOMMUNITY DYNAMICS IN ANTARCTIC MICROBIAL ORGANISMS

Dagmar Obbels[a], Elie Verleyen[a], Bjorn Tytgat[b], Pedro de Carvalho Maalouf[c], Aaike De Wever[d], Ines Tavernier[a], Caroline Souffreau[a], Yingjie Zhang[e], Joachim De Schrijver[f], Olivier Thas[e], Wim Van Criekinge[f], Annick Wilmotte[c], Anne Willems[b], Koen Sabbe[a] and Wim Vyverman[a]
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Keywords: Antarctica, biogeography, endemism

The acknowledgement that community composition within a local habitat is affected by both local and regional processes is one of the major achievements in community ecology within the past 50 years. However, for microorganisms, research programs aimed at testing the importance of local environmental conditions (lineage sorting) versus spatial factors (dispersal limitation) revealed contrasting results for different taxonomic groups, environments and spatial scales. Here we used Antarctic microbial communities as model systems to test the relative importance of both sets of factors in structuring the metacommunities of diatoms, green algae and prokaryotes in 41 lakes . Antarctica is a prime place for such studies because of (i) its geographic isolation and relatively pristine environments which minimize human-

induced introductions and (ii) the isolated nature of lakes in a matrix of ice and ocean. We used a polyphasic approach, and combined morphologic characterization of diatoms by microscopy, with molecular techniques such as Denaturing Gradient Gell Electrophoresis (green algae) and pyrosequencing (prokaryotes). A variation partitioning analysis revealed that geographical variables explained a significant part of the variation in the eukaryotic microorganisms, whereas they failed to significantly explain patterns in the prokaryotes. These results might explain the high amount of endemism found in diatoms and the finding that 20% of the Chlorophyte sequences had less than 97.5% similarity with a sequence in public databases. The observed contrasting patterns in metacommunity dynamics are, in part, likely related to cell size, and life cycle characteristics, such as the formation of spores and the presence of a sexual phase. We conclude that findings from one particular microbial group cannot be generalized to microbes as a whole and that for some groups such as green algae and diatoms, metacommunity dynamics are constrained by similar factors as those operating in larger organisms, whereas for others (prokaryotes) lineage sorting is likely to be the dominant process.

TITAN'S SEAS AND LAKES

Ozgur Karatekin
ORB

The Cassini spacecraft has revealed a vast set of lakes/seas filled or partially filled with liquid hydrocarbons and empty lake basins in the high latitudes of Titan. The lakes appear in various shapes and sizes and are filled with liquid hydrocarbons, primarily methane and ethane. In addition, the Cassini spacecraft provided observations suggesting for the first time temporal variations in lake surfaces. The variation in the shorelines can be explained by different hypothesis including evaporation and tides. During Titan's 16 day orbital period around Saturn, the time-dependent tidal response of the lakes may affect the shorelines although Titan's seasonal hydrologic cycle has likely to have much more significant effect. We will present the latest Cassini observations of the lakes/seas and the preliminary results on the numerical modeling of the tidal responses of the Ontario Lacus and Ligeia Mare.

THE TRAPPIST EXOPLANET PROGRAM

Michaël Gillon
Institut d'Astrophysique et de Géophysique, ULg for the TRAPPIST team

The hundreds of exoplanets known today allow us to put our own solar system in the broad context of our galaxy. In particular, the subset of known exoplanets that transit their parent stars are key objects for our understanding of the formation, evolution and properties of planetary systems. They represent the most direct shortcut to the detection of life outside our solar system. In this context, our team at Liege University has installed in 2010 at La Silla ESO Observatory (Chile) the robotic telescope TRAPPIST dedicated at 75% to the detection and characterization of transiting planets. I will give an overview of the TRAPPIST exoplanet program and its results acquired so far. I will focus on the potential of TRAPPIST and similar

telescopes for the detection of habitable terrestrial planets transiting nearby ultracool dwarfs and amenable for spectroscopic atmospheric studies.
I will also briefly present the result of a search for an habitable planet transiting a nearby M-dwarf performed with the Spitzer space telescope.

HOW THE INCIDENT FLUX FROM A STAR PACES THE PALEOCLIMATE ON HIS PLANETS? POSSIBLE EXTENSIONS OF THE TERRESTRIAL CASE.

Bernard De Saedeleer,
Georges Lemaître Center for Earth and Climate Research, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Life on a planet heavily depends on the climate prevailing on this planet. This climate is in turn mainly driven by the amount of energy received from the central star. The exact form of the incoming stellar radiation signal is set by the relative astronomical configuration of the celestial bodies, and by the planet's orbit and orientation (obliquity and precession). One can easily imagine that the range of possible astronomical configurations for the star-planet system is quite large, as is revealed by the various new planetary systems that have recently been discovered, e.g. by the NASA's Kepler mission.Here, we first explore the particular case of the planet Earth illuminated by the Sun as a generic example for illustrating how this astronomical forcing acts on paleoclimates in general. In addition to the seasonal cycle driven by the obliquity, periods of ice accumulation and of ice caps melting then follow one another, causing glacial/interglacial cycles over long timescales. The astronomical forcing is often said to be a 'pacemaker' of Earth's ice ages (Hays et al. 1976). The underlying idea is that ice ages are a manifestation of dynamics internal to the climate system, but their timing is set by the astronomical forcing. This interpretation may be linked to the universal concept of synchronisation in nonlinear sciences and in dynamical system theory. Here, we go a step further in the study of such a synchronisation by investigating its robustness and uniqueness. A conceptual paleoclimatic model of these ice ages is used (a modified van der Pol relaxation oscillator). This model reasonably mimics the main features of available paleoclimatic records (ice cores).

By using an appropriate clustering technique, we discovered that the synchronisation is not unique, i.e. that multiple possible locking states (attracting climatic trajectories) could coexist for the system. The number of these is controlled by parameters such as the amplitude of the insolation forcing. This is a particularly interesting result, as there is an apparent contradiction with the uniqueness hypothesis of [Tziperman et al, "Consequences of pacing the Pleistocene 100 kyr ice ages by nonlinear phase locking to Milankovitch forcing. Paleoceanography", 21:PA4206, 2006]. By computing the local largest Lyapunov exponent, we also found that the synchronisation is not robust, as climatic orbits could diverge for some period of time (50 kyr typically). Moreover, the boundary of the basin of attraction is sometimes so close that a small perturbation could make climate to potentially jump from one to another climatic trajectory, reducing predictability of the timing of ice ages. Synchronisation maps obtained for the case of the quasiperiodic insolation forcing exhibit a peculiar feature of intermingled Arnold's tongues. This pattern brings lots of physically insight into the way the number of attractors is defined; it may indeed be related to the major components of the insolation forcing (obliquity and precession) in a striking way.

These results of course heavily depend on the exact form of the insolation signal and on the particular paleoclimatic model, but the methodology is general.

We then extend the scope of this study by indicating how the methodology used for studying the pacing of paleoclimates on Earth by the incoming solar radiation could also be applied to other planets of the solar system like Mars, which has a different insolation regime. Note that attempts to find an orbital signal in the polar layered deposits on Mars however usually fail by lack of an absolute chronology.

It is finally shown how the proposed methodology could also be further applied to other planetary systems, like for example to the exoplanets Kepler-34b and Kepler-35b, for which the double star introduces yet another level of complexity in the insolation signal.

A 3-D DYNAMICAL STUDY OF THE HABITABLE ZONES OF EXTRASOLAR PLANETARY SYSTEMS

Anne-Sophie Libert
(Department of Mathematics, University of Namur (FUNDP) – naXys)

Habitability of earth-like planets in extrasolar systems requires their orbital stability over significant length of time. Several studies investigate the stability of hypothetical earth-mass planets in the planetary systems discovered so far, under the assumption of coplanar orbits. Recently, the possibility that extrasolar systems can be '3-D systems', namely they are composed of two or more planets whose orbital planes have substantial values of mutual inclinations, has been considered. Some analytical studies have highlighted that such systems can be long-term stable, and a first observational confirmation has estimated the mutual inclination of the orbital planes of planets c and d of the Upsilon Andromedae system to 30°. In this work, we discuss the influence of an eccentric giant planet on the long-term evolution of a fictitious Earth-mass companion on inclined orbit. Our results show that an Earth-planet below a critical inclination of approximately 40° (Kozai's value) is in a stable configuration with the gas giant and exhibits non-negligible variations in eccentricity. Moreover, we identify a region around 35° consisting of long-time stable and quasi-circular orbits, which could belong to the habitable zone of the system and be of particular interest for the research of life in extrasolar systems.