Missions to Habitable Worlds

Budapest, 28-29 October 2015

International conference on astrobiology and next space missions, organized by the COST TD 1308 action and the Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences

Sponsors:

- COST TD1308 action
- Hungarian Academy of Sciences
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Missions to Habitable Worlds

International conference on astrobiology and ESA missions, organized by COST TD 1308 action and MTA CSFK.

The conference takes place in Budapest, Hungary, to oversee astrobiology relevant aspects of next generation space missions, including Solar System exploration and space telescopes for exoplanet characterization, mainly coordinated by ESA.

The two day long meeting takes place at the main building of the Hungarian Academy of Sciences (can be seen the back cover) on 28-29 of October 2015. During the conference review presentations are given by experts and mission specialists of ongoing and planned space missions (including ExoMars, JUICE, CHEOPS, PLATO etc.) that support the understanding of the origin and evolution of life beyond the Earth. Beside overview talks, emphasis will be given on certain specific research topics, including analogue field activity and planetary protection issues. The meeting consists of two panel discussions: 1. on how to approach habitability from different disciplines (astronomy, biology, chemistry, Earth sciences, philosophy) and 2. on interdisciplinary research in astrobiology in Europe with the initiative of the future European Astrobiology Institute.

For more information on the meeting see the website: http://life-origins2015.csfk.mta.hu and also the website of the action: http://life-origins.com.

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- **Cs. Kiss** (Hungary)
- **L. Kiss** (Hungary)
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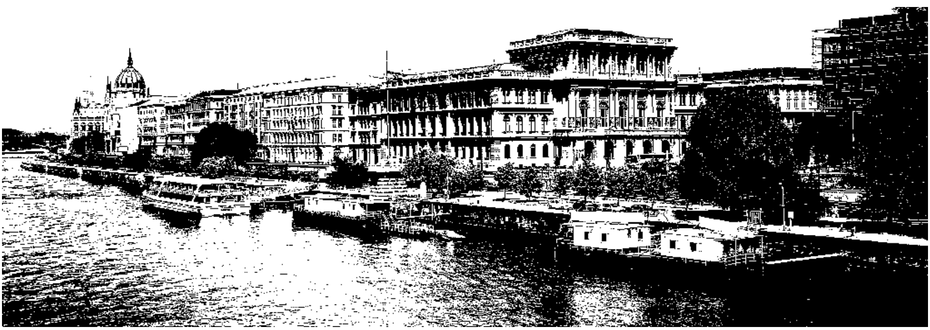
Background information on the meeting

The organizer: ORIGINS is a Trans Domain European COST Action (TD1308) dedicated to the scientific investigation of the origins and evolution of life on Earth, its possible distribution elsewhere in the Universe and the question of habitability of other planets.

Where, when and how did life appear on Earth? Has life developed elsewhere in the Universe? These fundamental questions have fascinated humanity since antiquity. However, it is only now that results from recent Solar System and exoplanets space missions (e.g. Mars Science Laboratory, Cassini-Huygens, Curiosity, CoRot, Kepler, etc.) have provided the opportunity for an integrated research programme that can answer, at least partly, these crucial questions. Such a programme necessitates a transdisciplinary approach, thus this project involves astronomers, astrochemists, planetologists, space scientists and engineers, geologists, chemists, palaeontologists, biologists, philosophers and historians of science.

The TD1308 action's aim is to develop and improve the research, training and outreach necessary for such a scientific programme and to support the establishment of the European Astrobiology Institute. There are 29 European countries that are part of this action, and several laboratories from 5 non-european countries (USA, Canada, South Africa, Australia, Russia) have also joined the action. The activities are running under five Working Groups: WG1 – Planetary Systems, WG2 – Origins of life, WG3 – Tracing the origins, WG4 – Detecting life, WG5 - History and Philosophy, and also under a Training/Education (Team1) and an Outreach/Dissemination (Team2) groups. The Action has specifically excluded the search for intelligent extraterrestrial life in its portfolio. Creationist theorems are also outside the Action's remit.

The Hungarian contributor in the conference is the Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences (its main building can be seen below).



Satellite meetings

Core Group meeting of the COST TD 1308 action

Two days before the conference, on 26 afternoon and 27 of October the core group meeting of the COST TD 1308 action will take place at the Konkoly Astronomical Institute (also known as Konkoly Observatory).

Societal and Ethical Aspects of Astrobiology in Europe - White Paper Compilation Meeting

On the day after the conference, on 30 October, the White Paper writing workshop of the WG5 group of the COST TD 1308 action will take place at the Konkoly Astronomical Institute (Konkoly Observatory). The invitation only meeting is to start the compilation of a white paper for decision makers and the public on the societal, ethical and economical aspects of astrobiology research in Europe, and the rationality of the realization of a joint institute titled European Astrobiology Institute.

Travel to the Astronomical Institute (26-27 Oct CG meeting, 30 Oct WG5 meeting)

The institute (address: 1121 Budapest, Konkoly Thege Miklós út 15-17. see the QR code below) can be reached by metro line 2 and bus no. 21 or 21A. Get off the metro at "Szell Kalman ter" station (former "Moszkva tér" station) and take the bus no. 21 or 21A. If you get on 21A you need to get off at the last stop ("Normafa") at the top of the hill. From this location you need to walk 5 min. toward west along the "Konkoly Thege Miklos" road. (When arriving at Normafa station it is strongly recommended to take a short walk toward east where you will find a large meadow with nice panorama to Budapest toward the slope of the hill.) The bus no. 21 keeps on travelling further, and turns left at Normafa (where bus 21A has its final station) and you need to get off at the next stop after "Normafa" called "Csillagvizsgáló". Right next to the bus stop you will find a garden gate with instructions on it.

Program

Day 1. (28 October)

08.30 **Opening talk** (László Szarka, Fruzsina Tari) **logistics** (Ákos Kereszturi)

Next Solar System missions I.
chairs: Olga Prieto-Ballesteros, John Brucato

09.00 **Astrobiology in ESA missions** (Luigi Colangeli) 12

09.30 **Mars sample return curation, planetary protection, and the science perspective** (Ludovic Ferriere) 14

10.00 **Habitability of the Martian north polar residual cap** (Anna Losiak) 20

10.15 ***Discussion***

10.30 Coffee break

Next Solar System missions II.
chairs: Frederic Foucher, Csaba Kiss

11.00 **Planetary evolution and life: Astrobiology from a planetary science perspective** (Tilman Spohn) 27

11.30 **Astrobiology aspects in the JUICE mission** (Olivier Grasset) 16

12.00 **Clathrate hydrates and habitability** (Olga Prieto-Ballesteros) 24

12.30 **Liquid water in the outer Solar System** (Csaba Kiss) 19

12.45 ***Discussion***

13.00 Lunch break

Next exoplanet missions
chairs: Szuszkiewicz E., László Kiss

14.00 **Searching for Traces of Life with the ExoMars Rover** (Jorge L. Vago) 29

14.30 **The quest for rocky planets** (Michel Mayor) 21

15.00 **The CHEOPS mission** (Alibert Yann) 31

15.30 **The PLATO 2.0 mission** (Heike Rauer) 26

16.00 Coffee break

Contributing Astrobiology talks
chairs: Emmanuele Javaux, Veronique Dehant

18.00 ***Discussion***

19.00 Conference dinner
(Sas Center Restaurant, 1051 Budapest, Sas u. 10.,
map can be seen on the back cover)

Day 2. (29 October)

Interdisciplinary view of habitability
chairs: Tilman Spohn, Péter Ábrahám, Ákos Kereszturi

10.30 Coffee break

12.10 **Roundtable discussion on habitability**

13.00 Lunch break

Analogues and planetary protection
chairs: John Brucato, Iván Almár

16.00 Coffee break

Policy and future of astrobiology
chairs: David Dunér, Stéphane Tirard

18.00 **Roundtable discussion on EAI initiative** (Muriel Gargaud, Wolf Geppert, Nigel Mason)

19.00 **End of conference**

19.30 Optional dinner
(Vakvarjú Restaurant, 1061 Budapest, Paulay Ede u. 7., map can be seen on the back cover)

MHW 2015

Abstracts

ordered alphabetically
by presenting author's lastname

1. Habitability: Biology point of view

Ricardo Amils

Centro de Astrobiología (CSIC-INTA) and Centro de Biología Molecular Severo Ochoa (CSIC-UAM), Madrid, Spain

Habitability is an important astrobiological concept that has an inevitable biological nature. From one site we are trying to determine the so call "limits of life", which are expanding continuously, and from the other trying to establish the planetary conditions that will favour life development. Obviously, the first has a dramatic influence on the second, because in recent times we learn that life is much more robust and resistant to extreme conditions than what we thought less than fifty years ago. Of the three conditions required for life: basic elements (C, O, H, N, S, Fe), energy (chemical or radiation) and an appropriate solvent (H_2O), we learn from astrophysicists that all of them are quite abundant in the universe. The most important limitation today is the phase state of the solvent, that to be operative must be in the liquid state. We will discuss the actual known environmental limits for life, the possible energy sources used by life systems, and the different type of possible solvents. We also will introduce the concept of terrestrial analogues and discuss the astrobiological importance of the recently discovered dark side of life.

2. Role of formamide in chemical evolution of biomolecules

Svatopluk Civiš, Martin Ferus

J. Heyrovsky Institute of Physical Chemistry of the ASCR, v. v. i., Prague, Czech Republic

Origin of basic molecules for the emergence of biomolecules, and life itself, is one of the fundamental questions of philosophy, religion, but also strictly rational and critical scientific research. Experiments dealing with the synthesis of amino acids in the discharge, nucleobases in a mixtures of cyanide and ammonia, carbohydrates from formaldehyde etc. were subjected to severe criticism due to the transformation of by the scientific community generally accepted theories about the environement and conditions before the emergence of the first living structures on early Earth. The current theories inclined to the view that the first living structures were based on ribonucleic acid molecule (RNA World), although the emergence of all the canonical bases of the genetic code in reasonably simple synthesis was practically an unresolved scientific problem until a few years ago. Although formamide was identified as potentially suitable parent compound, there are a few experiments in which all the nucleobases were synthetized in "one pot." In 2001, Italian chemists Saladino and Di Mauro published entirely new, fascinating theory that the parent molecule of compounds important for the origin of life could be sufficiently reactive molecule containing all four basic biological macro-elements, i. e. formamide ($HCONH_2$). Despite significant progress in this field, there are still remain many white spots in knowledge of chemical processes in formamide-based synthesis of biomolecules series. The answers are able to modify, change or entirely negate the theory of formamide based chemical evolution of biomolecules and life. Fundamental theory considers formamide as the parent compound of biomolecules and identifies its source in the hydrolysis of cyanide in seawater, in comets or parent molecular clouds of planetary systems. The latest results suggest that formamide and other compounds formed by the reaction of radicals with this molecule could also be merely a reactant or reactive intermediate in the formation of amino acids, nucleic bases and sugars in a variety of systems containing combinations in space probably far more common basic compounds of biological macro-elements (NH_3, HCHO, H_2O, N_2, CH_3OH, CH_4, CH_3CN). We employed infrared Fourier transform spectroscopy to detect reactive intermediates, radicals, molecules ions, and stable products in the plasma of electric discharge and laser plasma (3 TW in one laser shot using large laser facility PALS) in mixtures of prebiotic relevant molecules (e.g. $HCONH_2$, NH_3, HCHO, H_2O, N_2, CH_3OH, CH_4, CH_3CN) in the presence of catalysts relevant to prebiotic chemistry. Based on the analysis, the results are used to identify if formamide or relevant intermediates play a role of parent compounds, intermediates or if they are not important in the studied systems.

3. Astrobiology in ESA missions

Luigi Colangeli

Head of the Coordination Office for the Scientific Programme, Directorate of Science and Robotic Exploration, European Space Agency, Noordwijk, The Netherlands

The Science and Robotic Exploration Directorate is in charge of developing the “Science Mandatory Programme”. Through the science programme, ESA implements scientific projects to achieve ambitious objectives. On this ground, science challenges and advancement in technologies work together in a synergistic endeavour. Both long-term science planning and mission calls are bottom-up processes, relying on broad community input and peer review. The Cosmic Vision program is since 2005 the implementation tool to prepare the missions in the science mandatory program. I will present an overview of the space missions in operation, under development and for study with particular emphasis on those with impact in the astrobiology field.

4. Habitability: Chemist point of view

Gregoire Danger

Astrochemistry Group, Laboratory "Physique des Interactions Ioniques et Moléculaires", Université d'Aix-Marseille, Marseille, France

The question of the habitability concept for a chemist is not obvious. It is often considered that if water and organic matter are found in an environment, the habitability concept is running and life is not far away. However, even if water and organic matter are obviously necessary, they cannot alone be sufficient to qualify an environment as habitable.

Most of the organic matter present in the Universe is formed and evolves in dense molecular clouds. During the evolution of dust grains, covered with molecular dirty ice, they undergoes many chemical changes (ion bombardment, UV irradiation and thermal effects) to yield a highly complex organic matrix. The interstellar grains may then form agglomerates or planetesimals that are the parent bodies of meteorites found on Erath, known as asteroids and/or comets. Next to endogenously formed organic matter (for example in a planetary atmosphere), these small objects can serve as a reservoir of organic matter for the development of a prebiotic chemistry on the surface of Earth-like planets. This kind of chemistry could occur in environments enabling the development of chemical networks continuously fed with matter and free energy that allows the self-organisation of organic matter, an essential step for starting a prebiotic chemistry. This is the prelude to the emergence of biochemical systems that presumably contained molecules able to replicate, possibly through autocatalytic reactions, the only ones that will allow a very fast development following an exponential law. Replication and self-organisation are central to the problem of the origin of life if our knowledge is indeed only based on life as we know it on the Erath.

Our understanding of this chemical evolution should lead us to constrain the Habitability concept by highlighting the chemical conditions needed for the emergence of a real prebiotic chemistry at the surface of planets. This kind of evolution may be accessible to experimentation by following, in a holistic fashion the interaction of organic matter with a specific environment such as the one that may have occurred on the primitive Earth.

5. What makes an exomoon habitable?

Vera Dobos

Konkoly Thege Miklos Astronomical Institute, Hungarian Academy of Sciences, Budapest, Hungary

Beside stellar radiation, there are other heat sources too that can influence the habitability of an exomoon. Tidal heating is one of the most important ones, because it can dramatically change the environment of the surface. We applied a viscoelastic model for the first time to describe the tidal heating in exomoons (Dobos & Turner, 2015). This model is more realistic than other widely used models, because it describes the melting of the material inside the body. We defined the circumplanetary Tidal Temperate Zone (TTZ) and we have found that our model predicts 2.8 times more exomoons in the TTZ than the non-viscoelastic models with orbital periods between 0.1 and 3.5 days for plausible distributions of physical and orbital parameters. The viscoelastic model gives more promising results in terms of habitability, because the inner melting moderates the surface temperature, acting like a thermostat. Tidal heating can play a key role in the habitability of icy moons too, because the inner heat can melt the ice, making a huge ice covered subsurface ocean where life may appear. To determine whether an exomoon is icy, we propose estimating its albedo from the occultation light curve (Dobos et al., 2015). We calculated the depth of the moon's occultation in the light curve and the time duration of the measured phenomenon for different stellar masses and exomoon sizes. We found that albedo estimation by this method is not feasible for moons of solar-like stars, but next generation space missions may be capable of the observation of large icy satellites around small M dwarfs. For example, a 2.5 Earth-radii icy satellite in a circular orbit at the snowline of a 0.12 stellar mass star produces approximately 10 ppm depth in the occultation light curve, which is in the same order of magnitude as the expected precision of Plato 2.0 (27 ppm/hour) and CHEOPS (17 ppm/hour). Our results suggest that the occultation of the moon would last one hour in this case. We conclude that such detections may be successful with repeated observations, and that reaching 5 ppm photometric precision would be a significant milestone in albedo estimations.

6. Mars sample return curation, planetary protection, and the science perspective

Ludovic Ferrière

Natural History Museum, Vienna, Austria

Extraterrestrial samples in the form of meteorites have been curated for almost two and a half centuries. With the Apollo missions and the return of precious lunar samples on Earth, specific facilities have been designed. Scientists and governments have defined strict rules to prevent cross-contamination between Earth and other solar system objects (see the Outer Space Treaty, 1967). More recently, new facilities have been designed for the curation of asteroid samples, however, within the plan of Mars sample return missions in the next decades, a specific facility should be planned and constructed with respect to preventing sample contamination and alteration on the one hand, and preventing potential biohazards from the sample on the other hand. For samples returned from Mars, detection of life is a very important topic, not only in terms of the "planetary protection perspective" (i.e., these samples are regarded as having the potential of containing life or signatures of life), but in the "science perspective" (i.e., to know whether life ever arose on Mars). Accordingly, specific and appropriate handling and analysis of these samples will be required.

The EURO-CARES multinational project funded under the European Commission's Horizon2020 research programme (www.euro-cares.com) aims at designing such a state-of-the-art facility to receive, contain, and curate extraterrestrial samples (from asteroids, Mars, the Moon, and comets) while guaranteeing terrestrial planetary protection. Designing such a European Extraterrestrial Sample Curation Facility (ESCF) raises a lot of issues and questions for and from the scientific community: What are the best conditions to curate samples from Mars to keep them as pristine as possible? What kind of tests/experiments, destructive or not, have to be conducted to assess the presence of (potentially harmful living) extraterrestrial organisms in the returned samples? How much of the limited amount of available samples versus analog materials should be used for these tests to obtain reliable results? If there is "life" in the samples, should they be sterilized to allow sample distribution to the scientific community, or should (all) the investigations be conducted inside the ESCF? To answer some of these crucial questions and others that will arise, we are looking forward to the input and expertise from planetary scientists, in particular from the astrobiology community, as well as from biosafety laboratories, cleanroom manufacturers, electronics and pharmaceutical companies, nuclear industry, etc.

7. Analogues for planetary missions

Frédéric Foucher, Frances Westall, Jutta Zipfel, Nicolas Bost et al.

Centre de Biopgysique Moléculaire, CNRS, Orléans, France

Analogue sites and samples are used in space exploration for many purposes: to test space craft landing and rovers mobility, to test and calibrate instruments and sample preparation systems for in situ missions before launch, to help interpretation of data acquired during missions, and to carry out laboratory experiments. Analogue samples are complementary to the calibration samples used during instrument development, which are not necessarily relevant to the extraterrestrial body being studied (such as a colour target used to calibrate a camera or a piece of silicon used to calibrate a Raman spectrometer, for example).

Most of the in situ investigations dedicated to astrobiology were, are and will be focused on solid materials, including rocks, soil, and ices. However, natural rocks can be very complex in composition and the potential traces of life they could contain may be very subtle and challenging to detect using in situ instrumentation. It is therefore crucial to cross-calibrate the payload of a mission before launch using analogue samples. Thus, we have developed a collection of analogue rocks, the International Space Analogues Rockstore (ISAR, www.isar.cnrs-orleans.fr) in Orléans (France) that can be used to test and calibrate space instruments. This collection was used to make a "Blind Test" consisting of analysis of two unknown samples using a part of the ExoMars payload, including the RLS instrument. Each instrumental analysis was presented to geologists having no prior knowledge of the rocks, who then proceeded to a geological interpretation. The geologists were able to make relatively detailed interpretations, demonstrating thus that the use of the complementary payload can compensate for the technical limitations of the instruments (compared to laboratory instruments).

Analogue samples will also be crucial to test and calibrate instruments for a future European curation facility under consideration in the framework of the EuroCares project. These samples will include minerals and rocks as well as chemical, biological and material samples.

8. Astrobiology aspects in the JUICE mission

Olivier Grasset

University of Nantes - Planetology and Geodynamics, Nantes, France

The focus of JUICE is to characterise the conditions that might have led to the emergence of habitable environments among the Jovian icy satellites, with special emphasis on the three worlds, Ganymede, Europa, and Callisto, likely hosting internal oceans. Ganymede, the largest moon in the Solar System, is identified as a high-priority target because it provides a natural laboratory for analysis of the nature, evolution and potential habitability of icy worlds and waterworlds in general, but also because of the role it plays within the system of Galilean satellites, and its unique magnetic and plasma interactions with the surrounding Jovian environment. The mission also focuses on characterising the diversity of coupling processes and exchanges in the Jupiter system that are responsible for the changes in surface, ionospheric and exospheric environments at Ganymede, Europa and Callisto from short-term to geological time scales.

The overarching theme for JUICE is: The emergence of habitable worlds around gas giants. At Ganymede, the mission will characterise in detail the ocean layers; provide topographical, geological and compositional mapping of the surface; study the physical properties of the icy crusts; characterise the internal mass distribution, investigate the exosphere; study Ganymede's intrinsic magnetic field and its interactions with the Jovian magnetosphere. For Europa, the focus will be on the non-ice chemistry, understanding the formation of surface features and subsurface sounding of the icy crust over recently active regions. Callisto will be explored as a witness of the early solar system trying to also elucidate the mystery of its internal structure.

9. Analog missions of the Austrian Space Forum

Gernot Groemer

Austrian Space Forum, Innsbruck, Austria

In the last decade, the Austrian Space Forum has conducted 11 Mars analog field campaigns studying the science operational workflows for human-robotic surface missions. This has involved a series of robotic vehicles, spacesuit simulators, geoscientific and astrobiological instruments and a Mission Support Center located in Austria in the framework of the PolAres programme.

We report on the evolution of mission operations and science tactics over time and on the advantages of embedding traditional instrument field testing into an operational workflow as pertinent to a future human Mars mission. Exemplified through the MARS2013 simulation in the Northern Sahara, Morocco and the AMADEE-15 mission at the Kaunertal glacier in Austria, two major campaigns are described which involved a multidisciplinary team from 20 countries and a total of 32 experiments have been conducted in the fields of robotics, astrobiology, geosciences, human factors, and mission operations.

We compare these missions with the NASA Design Reference Architecture to demonstrate their contribution to prioritizing science in exploration missions and what kind of research can be expected from these integrated field campaigns.

10. Astrophysical conditions for planetary habitability

Manuel Guedel

University of Vienna, Vienna, Austria

"Habitability", a concept based on the potential existence of liquid water on the surface of a planet, depends on numerous astrophysical factors, apart from geophysical processes. In this presentation, I discuss some of the crucial astrophysical processes and parameters that determine habitable conditions, among them variable stellar ultraviolet (UV), extreme ultraviolet (EUV), and X-ray radiation that heats, ionizes and chemically processes upper planetary atmospheres; furthermore, stellar and interplanetary magnetic fields, ionized winds and high-energy particles interacting with planetary atmospheres and magnetospheres and driving atmospheric erosion. Evolutionary trends both of the star, its output, and planetary atmospheres need to be taken into account, as do initial conditions of planet formation in the protoplanetary disk phase. Furthermore, habitability is influenced by dynamical effects in multi-planet systems or in binaries, and by the presence of and interactions with small bodies.

11. Habitability: geosciences point of view

Martin Hervé

Laboratoire Magmas et Volcans, CNRS, Université Blaise Pascal, Clermont Ferrand, France

From the point of view of habitability, the early evolution of the Earth can be subdivided into four main periods:

1) From -4.568 to -4.4 Ga, most of the Earth's mantle was molten and a magma ocean covered the surface of our planet; which precluded the presence of liquid water or continent. In addition, meteoritic bombardment, linked to the end of planetary accretion, was intense. Obviously, this period would have been unfavourable to prebiotic chemistry and therefore to the appearance and development of life.

2) From -4.4 to -4.0 Ga, the Earth had continents, oceans of liquid water, and it was protected from the solar wind by its magnetic field. The meteoritic bombardment was reduced (cool early Earth). Therefore, although we have no evidence of any trace of Hadean life, all the conditions required for its emergence were satisfied: the terrestrial environment was potentially favourable to the appearance and development of life.

3) From -4.0 Ga (Archaean) up to today, the environmental conditions were not only favourable to the appearance of life, but they also allowed and favoured its development and diversification: Earth was inhabited.

4) However, a big uncertainty remains, it is relative to the role that the Late Heavy Bombardment could have played. In the case where life would have already appeared on Earth before -4.0 Ga, the question is to know if the intensity of the Late Heavy

Bombardment has been sufficient to sterilize the entire surface of the Earth, and therefore to eradicate any trace of a potential Hadean life.

12. Liquid water in the outer Solar System

Csaba Kiss[1], A. Takács-Farkas[1,2], S.J. Mojzsis[3]

[1] *Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Budapest, Hungary*

[2] *Loránd Eötvös University, Faculty of Sciences, Budapest, Hungary*

[3] *Department of Geological Sciences, NASA Lunar Science Institute, Center for Lunar Origin and Evolution (CLOE), University of Colorado, USA*

Planetary habitability is often characterised by the presence of liquid water. While it is usually considered at the surface of planets, it may also be present in the interior of dwarf planets and moons of giant planet system, far away from a typical "habitability zone". The heat necessary to maintain a liquid subsurface ocean may originate from tidal forces, but also from pure radioactive decay if the body has a massive enough core. In this talk we review the internal structure models of moons, dwarf planets, and dwarf planet candidates in the Kuiper belt of our Solar System, applying the latest available information on size and mass. We provide a list of objects that are candidates for an existing liquid water layer under their surface, and give an estimate for the total amount of liquid water in the Kuiper belt. With certain assumptions, this latter may exceed the total amount of liquid water on Earth at present, and should have been by far more massive in the early Solar System. In young planetary systems planete-simals in a debris disk are likely the dominant reservoir of liquid water.

13. Transits in the Solar System and the composition of the exoplanet atmospheres

Pauli E. Laine

Department of Computer Science and Information Systems, University of Jyvaskyla, Jyvaskyla, Finland

Our knowledge about exoplanets depends on very limited measurements and resolution. Atmospheric compositions are limited only to hot Jupiters and Neptunes. Detection of possible biosignatures on Earth-sized planets is not possible today. However, upcoming space missions, like e.g. TESS, JWST, CHEOPS, and PLATO will give us unprecedented access to exoplanet light curves. Before the new results arrive, it could be useful to collect the only known living planet's and other well-known other planet's light curves for the future comparison and habitability modelling. For this, we need to seek possibilities to measure Earth's and other terrestrial planet's transits from different locations in the Solar System. I will present some past events and experiments, potential locations and events, probes, and their instruments that could be used, as well some limitations and challenges.

14. Habitability of the Martian north polar residual cap

Anna Losiak[1], Leszek Czechowski[2], Michael A. Velbel[3]

[1] *Institute of Geological Sciences, Polish Academy of Sciences, Poland*

[2] *Institute of Geophysics, University of Warsaw, Poland*

[3] *Department of Geological Sciences, Michigan State University, United States*

The sulphate-rich deposits present on the surface of Mars were probably formed by the in-ice weathering of basaltic dust (as suggested by Catling et al. 2006, Zolotov and Mironenko 2007, Niles and Michalski 2009, Masse et al. 2010). Stratigraphically young (Amazonian) age of the gypsum deposits within the Olympia Planum regionmay suggest that this process is currently active within the North Polar Residual Cap. Here, we use numerical modelling of heat transfer to show that during the warmest days of the summer, solar irradiation may be sufficient to melt pure water ice located below a layer of dark dust particles lying on the highly inclined, equator-facing slopes of the Martian North Polar Residual Cap. The existence of small amounts of liquid water close to the surface, even under current Martian conditions, has important implications for estimating the astrobiological potential of Mars.

15. Hydrothermalism (Jaroso) and Evaporites (Salinity crisis) in SE Spain: Implications for Mars exploration

Jesús Martínez-Frías[1,2]

1 *Instituto de Geociencias, IGEO (CSIC-UCM), Facultad de Ciencias Geológicas C/ José Antonio Novais*

[2] *Ciudad Universitaria, Madrid, Spain*

Mars' surface shows many geomorphological and mineralogical features which are indicative of a wetter past, with the presence of surface and sub-surface water, as well as an ancient "geological vitality" of the planet. It involves the development of diverse geological processes, including, among others, volcanism and hydrothermal and evaporitic episodes. Water-related sulfates (e.g. jarosite, gypsum) have been found in large quantities and widely spread on the surface of Mars, corresponding to different mineralogical associations and settings, which provide vital information for interpreting paleoenvironments and habitability.

The SE Mediterranean margin of the Iberian Peninsula is an extremely interesting area of synchronous interaction of tectonic, volcanic, evaporitic and mineralizing hydrothermal processes during the Upper Miocene. The Jaroso Hydrothermal System represents a late-volcanic episode including mineralizing hydrothermal processes, which is famous and well known for being the world type locality of jarosite. The Sorbas basin is characterized by thick evaporate layers (mainly gyspsum and halite), which were deposited as a consequence of the desiccation of the Mediterranean Sea (Messinnian Salinity Crisis). Our previous works had already suggested the significance of this region of SE Spain as a relevant analog for carrying out Mars-related studies.

Since the discovery of jarosite and gypsum-rich sites on Mars, numerous geological and multianalytical campaigns were carried out at the Jaroso and Sorbas areas. Most of them were organized in the framework of the future ExoMars mission. In this talk, a general overview of the features of both areas is given, describing the state of the art and the most recent scientific developments.

16. The quest for rocky planets

Michel Mayor

University of Geneva, Versoix, Switzerland

Observed statistical properties of extrasolar planets have demonstrated the very high occurrence of low mass planets. Both radial-velocity surveys and the Kepler space mission have revealed the high frequency of planets with masses similar to the Earth. Combined data from planetary transits and Doppler surveys offer the possibility to explore the bulk density of these planets. These first data allow an estimation of the upper limit for the mass of exoplanets.

However we are still missing to have a list of rocky planets within the habitable zone of solar-type stars. For future follow-up studies of their planetary atmospheres we must identify «earth-twins» hosted by stars as close as possible. I will discuss the difficulties and prospects to discover such planets.

17. The ethical dimensions of habitability

Tony Milligan

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Philosophical discussions of astrobiology have tended to centre upon two sorts of problems. Firstly, those associated with defining life or, if a formal definition is deemed unnecessary, then at least making sense of life, as opposed to non-life. And secondly, the problems associated with accounting for the ethical standing, if any, of the most rudimentary forms of life or of life as such, independent of how it is instantiated. What follows will be a provisional attempt to push a little further into the latter set of difficulties, a provisional account of the ethical difference that judgements about habitability might make, i.e. the ways in which they might give us reasons for action, reasons for protection and reasons for intervention.

18. Extracellular space of extremophiles as a potential source of biomarkers

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Extremophiles represent an enigmatic link between terrestrial and extraterrestrial environments, providing an understanding of the extent of biology on Earth and enabling to discover of its wider presence in the Universe. Extremophilic microbes are characterised by functional capabilities allowing them to survive in harsh and extreme environments. The primary place of extremophiles interaction with their challenging outer environment is an extracellular milieu. Many of extremophilic microbes are able to translocate the biologically active molecules (proteins and metabolites) across their cytoplasmic barrier and to subsequently secrete these compounds into the extracellular milieu. Extracellular molecules in the outer environment play important roles in the microbial physiology and communication responses, sensing the extreme environment, protecting against its damaging components and passaging the nutrients into the cells.

Rock-eating extremophiles represent an exciting field of research for the study of microbe-mineral interactions in order to find the unique biosignatures of life in the extreme conditions. The fundamental interactions occur at the microbe-mineral interface, including microbial adherence processes and exchange of electrons that possibly induces some processes of mineral dissolution. This interface is composed of secreted extracellular proteins, metabolites and other mineral compounds embedded in extracellular polymeric substances. Metallosphaera-sedula is a chemolithotrophicarchaeon, which thrives at 73°C and pH 2, using energy derived from metal oxidation at the edge of living limits. We have shown that M. sedula is able to live on and interact with minerals of non-terrestrial origin from a stony meteorite (an H5 ordinary chondrite NWA1172). The visualization of the microbe-mineral interface with electron microscopy techniques reveals specific attachment patterns of M. sedula grown on the surface of the meteorite. Preliminary SEM study of the meteorite surface indicates the presence of globular phosphorus-enriched aggregates (with size ranging from <0.5 to 5 µm for single globules) as a specific biosignature left upon M. sedula growth. Grown on meteorite, M. sedula is able to secrete proteins and metabolites at the microbe-mineral interface, the molecular content of which is currently being investigated by a number of biochemical and biophysical techniques.

Red pigmented, non-motile extremophile Deinococcusradiodurans is an extremely radioresistant bacteria, which is characterized by a very branched protection system against the lethal radiation stress. The molecular content (metabolites and proteins) of D. radiodurans extracellular milieu is a subject of on-going experiments to elucidate the extracellular alterations caused to Deinococci cells after the space exposure at low Earth orbit.

19. Geophysical limitations on the habitable zone: Volcanism and plate tectonics

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Planets are typically classified as potentially life-bearing planets (i.e. habitable planets) if they are rocky planets and if a liquid (e.g. water) could exist at the surface. The latter depends on several factors, like for example the amount of available solar energy, greenhouse effects in the atmosphere and an efficient CO_2-cycle. However, the definition of the habitable zone should be updated to include possible geophysical constraints that could potentially influence the CO_2-cycle. Planets like Mars without plate tectonics and no or only limited volcanic events can only be considered to be habitable at the inner boundary of the habitable zone, since the greenhouse effect needed to ensure liquid surface water farther away from the sun is strongly reduced. We investigate if the planet mass as well as the interior structure can set constraints on the occurrence of plate tectonics and outgassing, and therefore affect the habitable zone, using both parameterized evolution models and mantle convection simulations.

We find that plate tectonics, if it occurs, always leads to sufficient volcanic outgassing and therefore greenhouse effect needed for the outer boundary of the habitable zone (several tens of bar CO_2), see also. One-plate planets, however, may suffer strong volcanic limitations. The existence of a dense-enough CO_2 atmosphere allowing for the carbon-silicate cycle and release of carbon at the outer boundary of the habitable zone may be strongly limited for planets: 1) without plate tectonics, 2) with a large planet mass, and/or 3) a high iron content. Acknowledgements: This work has been funded by the Interuniversity Attraction Poles Programme initiated by the Belgian Science Policy Office through the Planet Topers alliance, and results within the collaboration of the COST Action TD 1308.

20. Interplanetary ethics and space missions

Erik Persson

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When sending missions to other worlds, be they planets, moons or asteroids, there are many problems to consider. One particular type of problem is the problems that have to do with value. Value questions are inherently tricky and it might be tempting to just ignore them. In my presentation I will explain why that is a really bad idea. I will also try to explain and throw some light on some of the value problems in connection with space exploration, and present some ideas about how to deal with them.

21. Galactic conditions for habitability

Nikos Prantzos

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I will discuss the concept of Galactic Habitable Zone (GHZ), which has been formulated about 15 years ago. In contrast to the much older concept of Circumstellar Habitable Zone the GHZ is poorly defined and its premises rely on shaky grounds. In particular, the possibility of substantial radial migration of stars in the Milky Way disk, as suggested by recent theoretical and observational developments, leaves little practical interest to the idea of GHZ.

22. Clathrate hydrates and habitability

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Search for habitability markers is priority in future space exploration missions. Several minerals are sensitive to specific factors that control the potential for the environment habitability (e.g. humidity, temperature, pressure). This is the case of some hydrated phases, like clathrate hydrates. These water---made solids entrap molecules containing essential elements for life such as methane or carbon dioxide when they crystallize at particular conditions. It is remarkable that in the Earth, their formation occurs associated to particular extreme ecosystems, while their destruction is argued as the catastrophic cause to explain some climatic change periods.

It is suggested that clathrate hydrates are present along the Solar System, including in Europa, Ganymede, Enceladus, Titan or Mars. We are conducting both, laboratory experiments and terrestrial analogues studies to understand the role of clathrate hydrates in several planetary environments. Relevant results about the effects of the clathrate formation/dissociation on aqueous salty systems are contrasted with the information regarding gas hydrate deposits of deep seafloor. Their implications on the geological activity and habitability of icy satellites and Mars will be discussed in this meeting.

23. Astrobiology and exploration: Beyond missions and science discoveries

Margaret Race

SETI Institute, Mountain View, United States

Astrobiology seeks evidence of 'life" beyond Earth – simple, complex or intelligent – with the overall objective of understanding the origin, diversity and future of life in the Universe, as well as our place in it. The searches and research involve many scientific disciplines, technologies, locations and methods, all seeking data indicative of 'other' life, using various approaches (follow the water; detect 'signals'; search for biogeochemical indictors or habitability, etc.) If and when verified evidence of other life is found, the discovery will surely be significant. Its meaning doubtless will be analyzed and interpreted from diverse scientific perspectives as we ponder the implications of living in a biological universe.

As advances in astrobiology weave a new understanding of the definition of life, and its emergence, evolution and future, it also intersects with deep questions about meaning by challenging foundational views about life, humanity's engagement with it, and our literal and figurative place in the Universe. These questions cut across interdisciplinary realms beyond the expertise of the scientific community. All legal, ethical, theological, and cultural systems are base on 'life as we know it' and astrobiology has begun to re-examine related fundamental assumptions, as well as our anthropocentrism and terra-centrism. Already, astrobiological exploration and searches have encountered questions in legal and policy realms – including planetary protection, safety and environmental concerns – on Earth and beyond. Similarly, there is need to understand the broader implications of astrobiology within other disciplines and areas that touch upon human and societal contexts of our science endeavours.

This presentation will discuss how advances in astrobiology research and exploration have already begun to affect humanity in the broadest sense. Looking ahead, it is appropriate and necessary to foster interaction and collaboration with experts in the social, behavioural, economic and other disciplines who can help address the many challenging human questions that astrobiology will continue to raise.

24. The PLATO 2.0 mission

Heike Rauer and the Plato Consortium

DLR Institute of Planetary Research, Berlin, Germany

The PLATO Mission has been selected for ESA's M3 launch opportunity. PLATO will discover and bulk characterise extrasolar planets around hundreds of thousands of stars. With launch foreseen in early 2024, PLATO will follow the very successful space missions CoRoT and Kepler, as well as ESA's first small mission CHEOPS and NASA's mission TESS. PLATO will carry out high-precision, long-term photometric and astroseismic monitoring of up to a million of stars covering over 50% of the sky, and significantly increase the number of characterized small planets around bright stars in comparison to the previous missions. Its exquisite sensitivity will ensure that it detects hundreds of small planets at intermediate distances, up to the habitable zone around solar-like stars. PLATO will characterize planets for their radius, mass, and age. It will provide the first large-scale catalogue of well-characterized small planets at intermediate orbital periods, relevant for a meaningful comparison to planet formation theories and providing targets for future atmosphere spectroscopy. This data base of bulk characterized small planets will provide a solid basis to put the Solar System into a wider context and allow for comparative exo-planetology. The talk will provide an overview of the PLATO mission and its science goals.

25. Space policy and astrobiology

Kai-Uwe Schrogl

European Space Agency, Paris, France

Astrobiology has a number of links with space policy. While it is not a centrepiece of space policies or programmes of major spacefaring international organisations or countries, it is nevertheless an important element touching various aspects in the broader space context. The presentation will start with the question of why we are conducting space activities. It will then narrow in on the theme of exploration and identify its political, societal, legal and ethical dimensions. Based on that it will look at astrobiology from the policy perspective also taking into account what might intervene with astrobiology as e.g. plans for mining celestial bodies. Finally, it provides an outline of how astrobiology can develop further in the policy field as well as what space law requirements might be upcoming in this context.

26. Planetary evolution and life: Astrobiology from a planetary science perspective

Tilman Spohn

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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 greenhousing 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 canthus 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.

27. Energetic processing of the icy surfaces of the icy moons

G. Strazzulla

INAF-Osservatorio Astrofisico, Catania, Italy

Bombardment by energetic ions and electrons from the magnetospheres of giant planets drive non-thermal chemical reactions on the surfaces of their icy moons. Such a processing is simulated in the laboratory, where pure ices (e.g. H_2O, NH_3, CO_2, SO_2 and many others) or mixtures are deposited at low temperature (10-150 K) and irradiated with energetic ions or electrons. If the thickness of the target is greater than the ion penetration depth, ions are implanted in the target and if they are reactive (e.g., H^+, Cn^+, Nn^+, On^+, Sn^+) have a chance, being stopped in the target, to form new species containing the projectile.

Here I present some of the results obtained so far, in particular: (1) H_2O_2 and ozone are formed by ion bombardment of water ice dominated mixtures. These oxidants might play a relevant role to substain a biosphere in the putative oceans of some icy moons. (2) Implantation of C and S ions indicate that some molecular species observed on icy planetary surfaces (e.g. CO_2 and hydrated sulfuric acid) could have been formed by implantation of ions that populate the jovian (and others) magnetosphere. In some instances implantation of magnetospheric ions is the main mechanism to initiate the so called sulfur and carbon cycles on the icy surfaces. (3) Electron bombardment of water-carbon dioxide mixtures produces carbonic acid that is stable at higher temperature. In turns the bombardment of carbonic acid re-produces carbon dioxide that exhibits a peculiar IR band shape at about 4.25 μm that well mimic the one observed on Ganymede and Callisto.

Such a kind of experiments are used to better understand existing data from space missions and to program the future observations by the programmed space missions, particularly JUICE (ESA).

28. Searching for Traces of Life with the ExoMars Rover

Jorge L. Vago[1], H. Svedhem[1], D. Rodionov[2] and the ExoMars Team

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Based on what we knew about planetary evolution in the 1970's, people took more or less for granted the presence of simple life forms on other planets. The 1976 Viking landers can be considered the first missions with a serious chance of discovering signs of life on Mars. That the landers did not provide conclusive evidence was not due to a lack of careful preparation. In fact, these missions were remarkable in many ways, particularly taking into account the technologies available at the time. If anything, the Viking results were a consequence of the manner in which the life questions were posed. The failure to detect organic molecules on Mars had an effect on all subsequent landed Mars missions, which thereafter focused mainly on geology.

In the mid 90's a group of European investigators worked to define what they thought would be necessary to tackle the life-on-Mars issue once again. Their recommendations gave rise to what would become the ExoMars Programme. Today ExoMars is an international collaboration between ESA and Roscosmos - with NASA contributions - to develop and launch two missions.

The 2016 ExoMars mission includes two elements: 1) the Trace Gas Orbiter (TGO) to study atmospheric trace gases and subsurface water with the goal to acquire information on possible on-going biological or hydrothermal rock alteration processes; and 2) Schiaparelli, a European Entry, Descent, and landing Demonstrator Module (EDM) to achieve a successful soft landing on Mars and demonstrate technologies for the 2018 mission landing. The TGO will also provide data communication services for surface missions, nominally, until end 2022. The mission will be launched in March 2016 using a Proton rocket and arrive to Mars in October 2016.

The 2018 ExoMars mission will deliver a 310-kg mass rover and an instrumented landed platform to the martian surface. The mission will pursue one of the outstanding questions of our time by attempting to establish whether life ever existed on Mars.

The rover will explore the landing site's geological environment and conduct a search for signs of past and present life. A drill will allow the rover to collect and analyse samples from outcrops and at depth. The subsurface sampling capability will provide the best chance to access and analyse well-preserved sedimentary deposits, possibly containing molecular biosignatures.

The rover's Pasteur payload includes: panoramic instruments (wide-angle and high-resolution cameras, an infrared spectrometer, a ground-penetrating radar, and a neutron detector); a subsurface drill capable of reaching a depth of 2 m to acquire specimens; contact instruments for studying rocks and collected samples (a close-up imager and an infrared spectrometer in the drill head); a Sample Preparation and Distribution System (SPDS); and the analytical laboratory, the latter including a visual and infrared imaging spectrometer, a Raman spectrometer, and a Laser-Desorption, Thermal-Volatilisation, Derivatisation, Gas Chromatograph Mass Spectrometer (LD + Der-TV GCMS). The very powerful combination of mobility with the ability to access subsurface locations where organic molecules may be well preserved is unique to this mission.

After the Rover will have egressed, the Platform will carry out scientific environmental measurements at the landing site. The mission is scheduled to launch in May 2018 on a Proton rocket, and arrive to Mars in January 2019.

Even in case of promising biosignature discoveries, confirmation of the results would require a more thorough analysis than can be performed by remote robotic means. For this reason, the long-term goal of ESA's Mars Exploration Programme remains an international Mars Sample Return (MSR) mission, sometime during the next decade. The ExoMars missions constitute a fundamental milestone for MSR, as they will make an important contribution toward determining what types of samples to return.

This presentation will discuss both missions but concentrate more on the ExoMars rover (including science objectives, instrumentation, and upcoming milestones), as well as briefly report on the progress achieved toward the identification of suitable landing sites.

29. Protecting the Bodies: An introduction to planetary protection

Michel Viso

CNES/DSP/SME, Paris, France

The outer space treaty (OST) referenced in the UN, entered in force in 1967 and is still organizing the space activities. The article nine of the OST is stating the cautions to be taken while exploring the bodies of the solar system or returning samples from those bodies. Then the committee for space research (COSPAR) proposed as recommendation a Planetary Protection Policy (PPP) which is regularly maintained and updated according with the science knowledge. Now this COSPAR planetary protection policy is referenced in the rules, regulations, or law of several countries and management instruction of space agencies.

There are two sides to this planetary protection policy. The forward contamination of celestial bodies to be explored robotically is the first side in order to avoid any harmful contamination which could impair future research of sign of life. The proposed measures are customized to each body and to each mission, depending on their type and goal.

The backward possible contamination while returning extraterrestrial samples is the other side of this PPP. It encompasses either the forward leg as well as the inbound ones. Measures are also adapted to the body and the probability of a local development of a form of life.

Practically planetary protection policy is considered as a soft law and the reference for the agencies or countries exploring celestial bodies. The proposed measures to be applied to the mission and the hardware have to be taken in account from the beginning of any exploration project. Now the Planetary protection policy is an essential tool to help and foster international cooperation for the future projects for exploration, sample return missions and possible manned exploration future projects.

30. The CHEOPS mission

Alibert Yann

Institute of Physics, University of Bern, Bern, Switzerland

CHEOPS is the first ESA S-class mission that aims at obtaining very precise transit light curves of planets already known to have a planetary companion. I will present the CHEOPS mission, its scientific goals, as well as the instrument and mission concept.

31. Unhabitability and habitability

Alibert Yann

*Institute of Physics, University of Bern,
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I will present in which extend non-habitability is a concept that is easier to define than habitability. I will then use this concept to derive the existence of a maximum radius of habitable planets. Indeed, assuming that the presence of a C cycle, as well as surface conditions compatible with the presence of liquid water, are necessary conditions for habitability, I will show that, for any given mass, there exist a maximum radius above which planets cannot be habitable.