PLANET TOPERS: PLANETS, TRACING THE TRANSFER, ORIGIN, PRESERVATION, AND EVOLUTION OF THEIR RESERVOIRS.

V. Dehant[1], T. Van Hoolst[1], D. Breuer[2], P. Claeys[3], V. Debaille[4], J. De Keyser[5], E. Javaux[6], S. Goderis[3], Ö. Karatekin[1], N. Mattielli[4], L. Noack[1], T. Spohn[2], **A.C. Vandaele**[5], F. Vanhaecke[7], V. Wilquet[5] and the Planet Topers group (see http://iuap-planet-topers.oma.be/partners.php), [1]*Royal Observatory of Belgium, 3 avenue Circulaire, Brussels, B-1180, Belgium,* [2]*Deutsche Zentrum für Luft- und Raumfahrt, Berlin, Germany,* [3]*Vrije Universiteit Brussel, Brussels, Belgium,* [4]*Université Libre de Bruxelles, Brussels, Belgium,* [5]*Belgian Institute for Space Aeronomy, Brussels, Belgium,* [6]*Université de Liège, 4000 Liège 1, Belgium,* [7]*Universiteit Gent, Ghent, Belgium.*

Introduction:

The PLANET TOPERS (Planets, Tracing the Transfer, Origin, Preservation, and Evolution of their ReservoirS) group is an Inter-university attraction pole (IAP) addressing the question of habitability in our Solar System (see http://iuap-planet-topers.oma.be/). Habitability is commonly understood as "the potential of an environment (past or present) to support life of any kind" [1]. Based on the only known example of Earth, the concept refers to whether environmental conditions are present for eventually supporting life, even if the latter does not currently exist [2]. Life includes properties such as consuming nutrients and producing waste, the ability to reproduce and grow, pass on genetic information, evolve, and adapt to the varying conditions on a planet [3]. Terrestrial life requires liquid water. The stability of liquid water at the surface of a planet defines a habitable zone (HZ) around a star. In the Solar System, it stretches between Venus and Mars, but excludes these two planets. If the greenhouse effect is taken into account, the habitable zone may have included early Mars while the case for Venus is still debated. Important geodynamic processes affect the habitability conditions of a planet.

Vision:

As envisaged by the group, this IAP develops and closely integrates the geophysical, geological, and biological aspects of habitability with a particular focus on Earth neighboring planets, Mars and Venus. It works in an interdisciplinary approach (see Figure 1) to understand habitability and in close collaboration with another group, the Helmholtz Alliance "Planetary Evolution and Life", which has similar objectives (see http://www.dlr.de/pf/en/desktopdefault.aspx/tabid-4843/).

The dynamic processes, e.g. internal dynamo, magnetic field, atmosphere, plate tectonics, mantle convection, volcanism, thermo-tectonic evolution, meteorite impacts, and erosion, modify the planetary surface, the possibility of liquid water, the thermal state, the energy budget and the availability of nutrients.

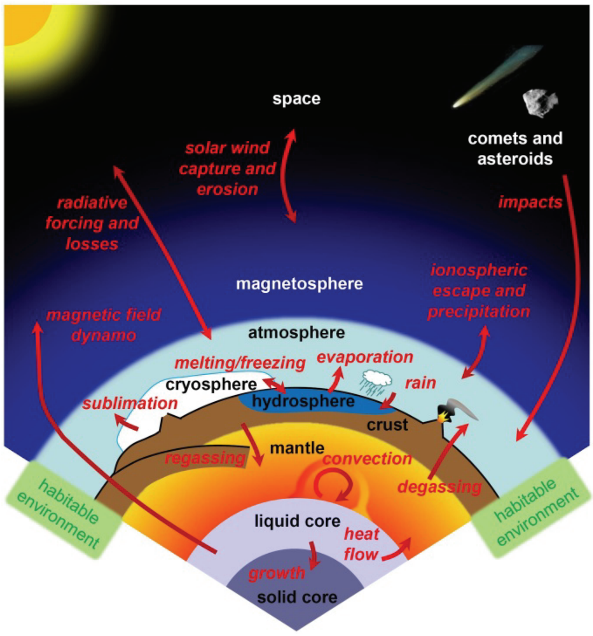

Figure 1: Interdisciplinary approach of PLANET TOPERS.

Shortly after formation (Hadean 4.4-4.0 Ga or billion years), evidence supports the presence of a liquid ocean and continental crust on Earth [4], Earth may have been habitable early on. The origin of life is not understood yet but the oldest putative traces of life occur in the early Archaean (~3.5 Ga).

Studies of early Earth habitats documented in rock containing traces of fossil life provide information about environmental conditions suitable for life beyond Earth, as well as methodologies for their identification and analyses. The extreme values of environmental conditions in which life thrives today also characterize the "envelope" of the existence of life and the range of potential extraterrestrial habitats. The requirement of nutrients for biosynthesis, growth, and reproduction suggest that a tectonically active planet, with liquid water is required to replenish nutrients and sustain life (as currently known). These dynamic processes play a key role in the apparition and persistence of life.

Content of the contribution:

This contribution focusses on the highlights of the work of the IAP Planet TOPERS [5]. The IAP Planet TOPERS field of research supports a broad community, which research themes are shown in the previous paragraphs. The Pole focusses its contribution on the full integration of these themes in the following Work Packages (WP) to better demonstrate how life can be sustained and to characterize the existence and persistence of life through the development of potential habitats.

WP 1: Internal Geophysics and Interaction with Atmosphere

The first work package studies key questions in the physics of the atmosphere and the interactions with planetary interiors. This includes the self-regulating (bio)geochemical cycles and models of mantle convection and tectonics in relation to magnetic field generation. The interactions between a solid and possibly partially liquid planet (existence of a liquid core) and its atmosphere encompass, in particular, the (partial) protection of the atmosphere from escape processes related to the existence of a magnetic field. The volatile exchange rates with the interior of the planet, and the dynamics of the interior are also of importance.

WP 2: Atmosphere and interaction with surface, hydrosphere, cryosphere, and space

The second work package deals with the thermal-chemical evolution of planetary atmospheres (net loss, sources and chemical reactions) and its interaction with surface, hydrosphere, cryosphere, and space to determine the evolution of pressure, temperature and composition in time, and the existence or not of liquid water. This includes the greenhouse effect as well as the regulating role of a magnetosphere on atmospheric losses. The comets and asteroids volatile mass influx from space into the atmosphere are dealt with as well.

WP 3: Identification of life tracers, and interactions with planetary evolution

The third work package is related to the identification and preservation of life tracers. Life leaves traces by modifying microscopically or macroscopically the physical-chemical characteristics of its environment. The extents of these modifications and their preservation determine the ability to (eventually) detect them. By characterizing chemical and morphological biosignatures on macro- to micro-scale, preservation and evolution of life in early Earth or analogue habitats are studied, with the objective to constrain the probability of detecting life beyond Earth and the technology needed to detect such traces. The Earth biosphere has been interacting with the atmosphere and crust at a planetary scale probably soon after its origin, in the Archaean, and most significantly since the 2.5 Ga oxygenation, with profound implications for planetary and biosphere evolution.

WP 4: Accretion and evolution of planetary systems

The fourth work package investigates the chronology of differentiation processes, the onset of plate tectonics and the recycling of the crust and implications for life sustainability. To that aim, samples from the worldwide meteorite collections are analyzed with the objective of relating their age (to be determined) and their composition to planetary evolution. The roles of asteroid and comet impacts in planetary evolution of the planets are also examined.

WP 5: Integration of information into "Global System dynamics": Case study and comparisons of evolution pathways; definition of habitability conditions and its sustainability on different bodies

The fifth work package will be addressed more lately as its aims at developing, in a holistic approach, an integrated model of planetary thermodynamic engine that includes mass, energy, and entropy balances into a "Global System dynamics". The roles of feedback cycles to stabilize habitable conditions are and will be examined. For instance the net loss or gain of volatiles in the atmosphere depends on the atmospheric pressure itself. Case studies and comparisons of evolution pathways, such as between Mars, Venus, and Earth are considered. Ultimately, a roadmap (in collaboration with the international community) for assessment of habitability on terrestrial bodies (terrestrial planets, asteroids, rocky and icy satellites, extrasolar terrestrial planets) will be provided.

References:

[1] Steele et al. (2005) http://mepag.jpl.nasa.gov/reports/archive.html.

[2] Javaux and Dehant (2010) *Astron. Astrophys. Rev.*, *18*, 383–416, DOI: 10.1007/s00159-010-0030-4.

[3] Sagan, (1970) *Encyclopedia Britannica*, 22, 964–981.

[4] Wilde et al. (2001) *Nature*, 409, 175–178.

[5] Dehant V., Breuer D., Claeys P., Debaille V., De Keyser J., Javaux E., Goderis S., Karatekin Ö., Spohn T., Vandaele A.C., Vanhaecke F., Van Hoolst T., and Wilquet V. (2012) From Meteorites to evolution and habitability of planets, Planet. *Space Sci.*, DOI: 10.1016/j.pss.2012.05.018.