PLANET TOPERS: Planets, Tracing the Transfer, Origin, Preservation, and Evolution of their ReservoirS

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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. Based on the only known example of Earth, the concept refers to whether environmental conditions exist that could support life, even if life does not currently exist. As surface conditions are largely affected by internal processes, the PLANET TOPERS group develops and closely integrates the geophysical, geological, and biological aspects of habitability with a particular focus on Earth neighboring planets, Mars and Venus.

Although alternative biochemistries have been hypothesized, extraterrestrial life would probably be based on organic chemistry requiring a liquid water solvent. The stability of liquid water at the surface of a planet has traditionally defined a habitable zone (HZ) around a star. In the Solar System, the classically defined HZ stretches between Venus and Mars. Depending on details of the models, Venus may have been in the habitable zone in the early solar system when the Sun was less luminous. Geological evidence suggests water on early Mars but how the greenhouse effect may have worked then is still debated. However, the conditions for habitability are more complex, and may include icy moons where subsurface liquid water is in contact with minerals. Several dynamic processes, e.g. internal dynamo, magnetic field, atmosphere, plate tectonics, mantle convection, volcanism, thermo-tectonic evolution, comet and meteorite impacts, and erosion, modify the planetary surface, the possibility to have liquid water, the thermal state, the energy budget and the availability of nutrients, and therefore ultimately play a crucial role in the habitability of a planet.

In order to understand habitability more deeply, we have worked on different complementary subjects and obtained interesting results that will be highlighted in this presentation. In particular, we have shown that Plate tectonics and continents seem to affect the ability of a planet to harbor life, and both are strongly influenced by the planetary interior (e.g. mantle temperature and rheology) and surface conditions (e.g. atmospheric temperature). We have also investigated the history of the atmosphere and surface conditions on terrestrial planets, focusing on mechanisms that deplete or replenish the atmosphere: volcanic degassing, atmospheric (hydrodynamic and non-thermal) escape, and impacts (volatile delivery as well as atmospheric loss). We have considered long term evolution through a coupled mantle/atmosphere model. The interrelation between interior and atmosphere includes for instance the role of water on volcanism and convection/thermal history/evolution, the role of trace gases such as methane and of methane clathrates (solid compounds similar to ice in which a large amount of methane is trapped within a crystal water structure), and the role of an impact on the thermal evolution of the mantle and on the atmospheric evolution.

We have also worked on the identification and preservation of life tracers (analytical protocols useful for paleobiology and exobiology) in early Earth and analog extreme environments, and on the implications for detection of life. This includes the examination of possible abiotic processes mimicking biological processes and products, as well as the identification of real biosignatures that could be used for the detection of life in early Earth and extraterrestrial records.

These studies are improving the characterization of interactions between the biosphere, the geosphere, and the atmosphere through time, linking to WPs of the IUAP Planet TOPERS.