SYEP 1: What makes an exoplanet habitable

Time: Wednesday 14:00–16:00 Location: Audimax

Invited Talk SYEP 1.1 Wed 14:00 Audimax
Requirements for Earth-like habitats — •Helmut Lammer — Austrian Academy of Sciences, Space Research Institute, Schmiedlstr. 6, 8042 Graz, Austria

Factors such as stellar and geophysical conditions that allow complex multi-cellular life forms to originate on terrestrial planets with N_2-O_2-dominated atmospheres, so-called Class I habitats, will be discussed. Recent findings on how earliest accretion processes set the initial parameter stages for terrestrial planets to end up as a Class I habitat are also addressed. Here, the focus will be i) on the lifetime of the protoplanetary disk, how fast a protoplanet can accrete mass within the gas disk so that Earth-size/mass planets may end up inside the habitable zone as sub-Neptunes with H_2-He-dominated atmospheres, and ii) on the availability of the initial amount of heat producing radioactive elements such as ^{40}K, ^{238}U, and ^{232}Th on early planets. These elements determine the heat production budget of a planet, which exerts a first order control on its thermal evolution, tectonics, and hence its likelihood for habitability. Since all three elements can be lost during planet formation, compared to Earth one can expect a wide diversity of planets inside the habitable zone with different heat budgets and tectonic regimes, resulting most likely in CO_2-dominated atmospheres. Finally, a new formula for the estimation of the number of possible Class I habitats in the Galaxy, which can be fine-tuned and constrained by the detection of main atmospheric constituends, obtained from future space and large ground-based telescopes, will be presented.

Invited Talk SYEP 1.2 Wed 14:30 Audimax
Geological drivers of habitability — •Raymond T. Pierrehumbert — University of Oxford

Atmospheres of rocky planets are dynamic entities, and their evolution is governed by the balance between outgassing from the planetary interior, crustal sinks of atmospheric or oceanic volatiles, and escape of volatiles to space. It is increasingly recognized that geological processes (and not just a planet's position in the nominal habitable zone) are crucial to determining habitability. The role of the deep carbon cycle in determining whether planets near the outer edge of the nominal habitable zone can maintain enough atmospheric CO2 to attain the maximum-greenhouse limit is particularly stark, but there are also issues regarding the circumstances in which the silicate weathering thermostat can prevent CO2 from building up to levels that render the planet uninhabitable. Geological processes also govern other aspects of atmospheric composition having a bearing on emergence of life (as we know it), and of interpretation of biosignatures. These include methane abundance and nitrogen cycling.

In this talk, I will review some of the key processes involved in geological drivers of habitability, including supply of uranium and thorium, representation of continental and seafloor weathering, composition of volcanic outgassing, and the role of magma oceans. Some remarks on special features of hydrogen-dominated atmospheres will be offered. A number of critical unresolved issues will be highlighted.

Invited Talk SYEP 1.3 Wed 15:00 Audimax
Space Weather from an Active Young Sun and Its Impact on Early Earth — •Vladimir Airapetian — NASA Goddard Space Flight Center/SEEC and American University

The early Solar System was a chaotic place, likely subject to frequent large impacts as well as the violently changing space weather (energetic ionizing radiation flux from the solar corona, wind and transient events) from the infant ($<$ 100 Myr) and toddler(400-600 Myr) Sun. Understanding the conditions that allowed for the emergence of life on early Earth, and whether other inner planets in our Solar System possibly also supported habitable conditions early in their histories is a promising way to address these questions. Thus, the knowledge of the heliospheric environments surrounding the early Venus, Earth and Mars is critical for evaluation of the basic requirements for life as we know it including liquid water and organic compounds. Here I will describe recent observations of young solar-like stars and the Sun as inputs for our 3D MHD models of the corona, the wind and transient events (flares, coronal mass ejections and solar energetic particle events) and discuss their impact on atmospheric erosion and chemistry of our planet. I will use these constrained energy fluxes to describe our recent atmospheric chemistry models impacted by energetic particles from the young Sun and formation and precipitation of biologically relevant molecules. I will then highlight our results of laboratory experiments of proton irradiation of mildly reduced gas mixtures and their implications to the climate, prebiotic chemistry and the rise of habitability on early Earth and young exoplanets.

Invited Talk SYEP 1.4 Wed 15:30 Audimax
Habitable zones around stars and the search for extraterrestrial life — •James F. Kasting — Penn State University, University Park, PA USA

All life on Earth depends on liquid water during at least part of its existence, and it is conservative to assume that life elsewhere has this same requirement. To be detectable remotely, life must also be able to colonize the surface of a planet so that it can modify the planet's atmosphere to an extent that would be detectable from a great distance. Hence, the habitable zone (HZ) around a star is typically defined as the region within which a rocky planet can support liquid water on its surface. The tools needed to estimate the boundaries of the HZ are those of meteorology: 1-D and 3-D climate models. I will discuss the current state of the art in HZ climate modeling, as well as future space telescopes that should eventually allow us to look for habitable planets around nearby stars and use spectroscopy to determine whether they are actually inhabited. NASA's James Webb Space Telescope, which launches in October, 2021, may be able to perform transit spectroscopy on some rocky planets orbiting M stars. Direct imaging of rocky planets around more Sun-like stars will require direct imaging space telescopes such as NASA's LUVOIR or HabEx, or ESA's LIFE (Large Interferometer for Exoplanets).