Project Title: Climates of exoplanets: multi-parameter exploration of the Habitable Zone

Supervisor: Laura Silva (laura.silva@inaf.it)

Project Description:

One of the main drivers of exoplanetary studies is the quest for inhabited worlds, the best candidates being rocky planets with temperate physical conditions. A growing number of rocky planets with Earth or super-Earth sizes are currently discovered. The technological advancements of the next years will gradually allow recording spectra of their thin atmospheres to search for atmospheric biomarkers. However, to attain such ambitious goals it is necessary to bolster these observational efforts with a proper support of modelization. Climate models are required to assess the surface conditions and habitability of individual exoplanets from a sparse set of experimental data. Climate models are also required to measure atmospheric abundances while searching for biosignatures.

In this framework, this PhD project aims at expanding the range of operation of climate models, traditionally built to describe the Earth System, to treat the wide range of terrestrial and non-terrestrial conditions that can be present in exoplanets.

This effort is necessary to expand the calculations of the Habitable Zone (HZ), which so far have largely relied on single atmospheric column calculations aimed at simulating planets in limiting conditions of insolation. In this project, the HZ calculations will be extended using more realistic climate models and treating additional climate factors, such as planetary rotation period, radius, axis tilt, surface geography, and atmospheric pressure and composition. One goal is to provide multidimensional calculations of the HZ in the parameter space defined by such climate factors (e.g. Murante et al. 2020). Another goal is to associate a quantitative index of surface habitability (e.g. Silva et al. 2017a,b) to each set of model parameters. With this approach it will become possible to rank the habitability of exoplanets in a more realistic, multidimensional space. This will allow us to prioritize the search for atmospheric biomarkers in targets with optimal conditions of habitability.

The PhD student will acquire the physical knowledge and the numerical skills to manage and to improve different aspects (e.g. radiative transfer, longitudinal transport, tidal locking) of existing climate models of different complexity, mainly ESTM (Vladilo et al. 2015), and models such as PlaSim. Data analysis tools (including machine learning approaches) will be applied to analyse the multi-parameter indices of habitability, to search for trends between the habitability and the planetary parameters known to force the climate system. The project will be carried out in collaboration mainly with researchers from OAT (S. Ivanovski, M. Maris, G. Murante, L. Silva, and G. Vladilo), and CNR/Pisa/Torino (A. Provenzale, J. von Hardenberg).