Project Title: Bridging galactic and planetary habitability

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Project Description:

The life cycle of gas, dust and stars in galaxies, driven by global properties (depth of the dark matter halo potential well, mass in baryons, environmental interactions, merging, etc), and local properties (SF, IMF, AGN, and feedbacks linking these local scales to the galactic ones) gives rise to spatial and temporal distributions of abundance of heavy elements, of massive stars exploding as CCSN, dead remnants, radiation field and matter density field. All these factors play a key role on the potential galactic habitability.

The elemental abundances of molecular clouds collapsing to form stars are inherited by the end products of star formation: protoplanetary disks and their ensuing planetary systems. Although the transition from disks to planetary systems is an extremely complex and still poorly understood process, the disk's metallicity, elemental ratios and dust to gas ratio are believed to play a fundamental role both in terms of probability of forming rocky vs gaseous planets and of final composition of the formed planets. These expectations are partly corroborated by challenging and controversial observations (of host stars abundances and of protoplanetary disks). A general guess is that a minimum amount of heavy elements are required in order to allow rocky planets formation. On the other hand, at large enough metallicity, the empirically found larger frequency of Jupiter-like planets may damp, via migration, the formation of rocky planets. Therefore different galactic regions and cosmic epochs would be differently able to host potentially habitable planets.

The aim of this PhD project is to couple simulations of rocky planets formation directly performed with models of protoplanetary disks to cosmological simulations of MW-type galaxies, by linking the information on composition and dust among the two scales. Complex problems in physics, resulting from the interplay and feedback of many processes at different scales, as is the case of planet formation and of the behavior of baryonic matter in galaxies, can in fact only be interpreted with numerical experiments. On one hand, we want to explore the challenging complex problem of planet formation probability, on the other, studies of galactic habitability are the only way to make statistical estimates on the distribution of potentially biosignature-hosting planets in the Galaxy in absence of direct detections. These statistics can be also applied to galactic sub-volumes that could be sampled by future surveys, as well as in SETI programs.

This project will allow the PhD student to acquire substantial numerical skills, necessary to code, set up, run and analyze both the protoplanetary disk (PHANTOM, Price et al. 2018, PASA, Vol. 35, e031, 82) and the galaxy cosmological (Gadget+MUPPI, Murante et al. 2015, 447, 178; Granato et al. 2021, MNRAS, 381) simulations. These are state-of-the-art codes, including a detailed treatment of elemental abundances and dust. We highlight the multidisciplinar character implied by this project that links research fields normally considered as non intersecting: galaxy and planetary formation linked within an astrobiological perspective. The project will be carried out in collaboration with G.L. Granato, S.L.Ivanovski, G. Murante, L. Silva and G. Vladilo, experts in the different implied topics, and with researchers from IATE and SISSA.