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Ground activities on astrobiology in Italy

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Abstract. In the frame of the recent emerging role of astrobiology in science and society, the Italian Space Agency has invested on ground-based research activity to support the future exploration program aimed at searching for life beyond Earth. In this context, the multi-disciplinary program "Life in Space" was funded with the aim to build a strong Italian community of astrobiologist for driving the future of space exploration in the next years. The Development of the next generation of scientist is a critical product of the program; this includes grant fellowships for undergraduates, graduates and postdoctoral positions. Additionally, the project gives strong emphasis to education and public outreach since the intrinsic public interest in astrobiology offers a crucial opportunity to educate and inspire future generations of scientists, technologists, and informed citizens.

Key words. Origin of life – Extremophiles – Planetary exploration – Exoplanets

1. Introduction

Astrobiology is defined as the study of the origin, evolution, distribution, and future of life in the universe. However, astrobiology can be defined as the integrative study of the interactions within and between the physical, chemical, biological, geological, planetary, and astrophysical disciplines as they relate to understanding how an environment transforms from nonliving to living and how life and its host environment coevolve, and how is the future of life on Earth (Fig. 1). As the above definition suggests, a systems-level view of the emergence of life that includes its environmental context, and how life and its environment subsequently changed together to maintain a habitable Earth, is leading to a new view of habitability. The concept of dynamic habitability drives the insight that habitability is more appropriately thought of as a continuum—that an environment may transition from inhabitable to habitable over different spatial and temporal scales as a function of planetary and environmental evolution, the presence of life, and the feedbacks between related complex physical, chemical, and biological parameters and processes. Planetary environments that may be habitable today or in the past are not necessarily the same as those that could have fostered the emergence of life. Evidence from major transitions in environmental conditions from early Earth to today, and an understanding of how they occurred, is critical for the search for life. A better understanding of the emerging concept of dynamic habitability come from studying the one inhabited planet currently known—Earth. The planetary environments of early Earth that gave rise to life remain poorly constrained. A better understanding of these environments entails a "mission to early Earth." Such a "mission" will, in the near term, integrate prebiotic chemistry, origins of life research, and early

Earth planetary conditions to understand their coevolution in the context of multiple parameters (including, e.g., temperature, pressure, and pH conditions) evolving over a range of spatial and temporal scales. Projecting forward, increased understanding of dynamic habitability and how life and its environment evolved together on Earth will allow questions to be addressed concerning which elements of planetary evolution are predictable and independent of biosphere evolution; what feedbacks exist between the biosphere and geosphere, including during long periods of quiescence; and how periods of catastrophic change affect the balance of influence between planetary dynamics and the biosphere. Although the research for these basic questions is most easily carried out on Earth, the far-reaching questions to be addressed in the next two decades demonstrate that dynamic habitability and the coevolution of planets and life provide a powerful comparative foundation upon which to integrate diverse astrobiology communities focusing on Earth, the solar system, stellar astronomy, and exoplanetary systems. Understanding dynamic habitability has been furthered by recent discoveries of microbial life in terrestrial place before thought to be completely sterile and by advances in investigations of extreme life and how it interacts with its environment on Earth. Identifying life in isolated refugia or ephemeral habitats on Earth (e.g., in the Atacama Desert, Antarctic subglacial lakes etc.) has emphasized that habitability, rather than being a binary state, is a continuum defined over varying time and spatial scales. Increasing understanding of the habitability of saline and hypersaline environments, life's limits in extreme environments, concurrent with the discovery of potential brines on Mars, has led to a resurgence in interest in adaptations of life to saline fluids. The recent discovery of communities existing in the subsurface of the ocean floor and continental lithosphere, away from the influence of the Sun's energy, has provided new models for rock-hosted, chemosynthetic life that may exist on other worlds.

2. Life in Space project

Over the past year, the Italian Space Agency (ASI) sponsored a number of astrobiological researches performed on-board the International Space Station; however due to limitations in terms of timeline, cost and access to spaceflight platforms, scientists rely heavily on ground-based activities. In this context and with the aim to better prepare future space exploration, ASI has financed an Italian program on astrobiological ground-based activities named "Life in Space: Origin, Presence, Persistence of Life in Space, from Molecules to Extremophiles" (Onofri et al. 2019), that aim to build a strong communities of Italian astrobiologist and to prepare future missions through ground researches. The project involves ten different institutions and universities, and people with different scientific background in order to build up a multidisciplinary and complementary group to achieve high-impact goals. The community have identified six major topics of research in the field: Synthesis and function of macromolecules in the origin of life, identifing, exploring and characterizing environments for habitability and biosignatures, atmospheric biosignatures and exoplanet. The first subgroup "Origins and Evolution of Organic Compounds" has the aim to study the formation of prebiotic organic compounds in simulated ice and gas conditions expected on Pluto, icy-moons and comets, and to study the prebiotic compounds synthesis in non-aqueous solvents such as liquid methane/ethane that is present on Titan, through both lab experiments and simulation model analyses. The "Prebiotic syntheses, Origins, and Early Life" group investigates the use of formamide as a precursor, in presence of minerals and simulated cosmic radiation, to obtain more complex organic substances and basic intermediates of cellular processes. So, the question arises: has our limited experience of habitability on Earth distorted our understanding of the basic set of requirements for a habitable world? And how does our experience serve as a helpful guide for the search for life beyond Earth? In order to shed lights to these questions, the "second group" of

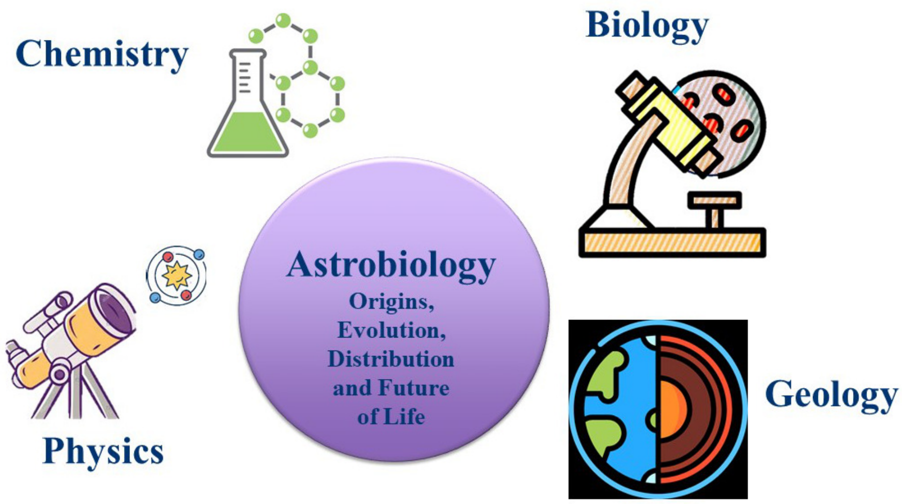

Fig. 1. Astrobiology is a multidisciplinary field that encompass Biology, Geology, Chemistry and Physic disciplines.

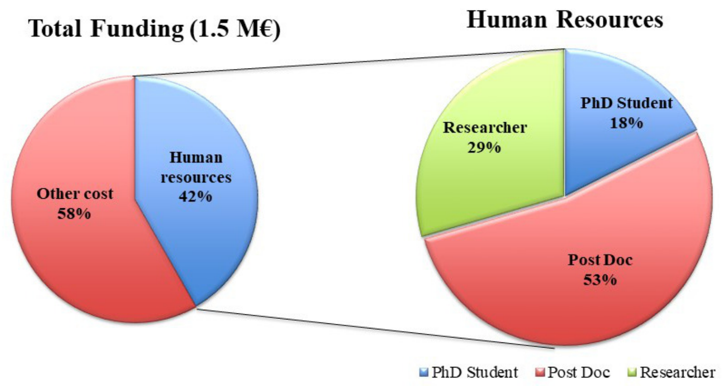

Fig. 2. 42 percent of 1.5 MEuro of total funding, that correspond to 630KEuro, is devoted to the human resources (PhD students, Post-doctoral grant and Researchers).

the project investigate the limits of terrestrial life in extreme environments, that for some characteristics can be considered analogues to extraterrestrial environments. This group focus on extremophiles, as Antarctic black fungi (Cassaro et al., this issue), desert cyanobacteria (Faraglione et al., this issue), thermophilic archaea (Cobucci-Ponzano et al., this issue), and microbiomes from extreme solfataric environments, with the aim to understand the limits of life on Earth through –omics approach. These kind of investigations gives input also for the search of life beyond Earth through the identification of biomolecules, defined as biosignatures, to be searched in the future exploration mission as NASA and ESA Mars missions (Vago et al. 2017).

References

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