

## **Hands-On Space Experiments: Out-of-School Astrobiology Activities at the University of Rome Tor Vergata**

Daniela Billi<sup>1\*</sup>, Alessandro Berlingeri<sup>2</sup>, Amedeo Balbi<sup>2</sup> and Liù M. Catena<sup>3</sup>

<sup>1</sup> University of Rome Tor Vergata, Department of Biology, Rome, Italy

<sup>2</sup> University of Rome Tor Vergata, Department of Physics, Rome, Italy

<sup>3</sup> University of Rome Tor Vergata, Center for Research and Continuing Education for the Teaching of Scientific Disciplines

\* Corresponding author: University of Rome Tor Vergata, Department of Biology, Via della Ricerca Scientifica snc, 00133, Rome Italy; billi@uniroma2.it

### **ABSTRACT**

In the 2014 edition of the *Stage a Tor Vergata* an Astrobiology module was organized as a “hands-on” approach to lead motivated and talented high-school students through cutting-edge experiments aimed at testing the limits of terrestrial life outside Earth, the identification of biosignatures for searching life on Mars, and the search for planetary systems around other stars. This “hands-on” approach introduced the students to laboratory procedures used to investigate the effects on cyanobacteria of space vacuum and UV radiation as expected in the next EXPOSE-R2 mission outside the International Space Station. Students also became familiar with techniques used to detect exoplanets and software applications that simulated the output of real observations. Data gathered by comparing pre- and post- internship learning tests showed a gain in the student’s perceived knowledge of astrobiology, while the analysis of the evaluation questionnaire revealed a positive effect. This internship and its future iteration are expected to increase the number of students enrolling in scientific degrees and, possibly, that of students choosing to dedicate their career to astrobiology.

**Keywords:** astrobiology, out-of-school activities

## Introduction

There is no doubt that due to its focus on the origin and distribution of life in the Universe, Astrobiology is a fascinating field for scientists but also for the general public. It is also unique in the way it fosters and relies on multidisciplinary: in this field, geologists collaborate with planetary physicists, biologists talk to astrophysicists and chemists examine satellite data from other planets. In view of its multidisciplinary nature and appeal, astrobiology has the potential to engage students with science by making them witnesses of cutting-edge space research. Out-of-school astrobiology programs have consequently been shown to improve students' understanding of the nature and processes of science and to raise their interest in a career in science. Examples are given by programs such as “Pathways to Space” at the Powerhouse Museum (Sydney), “Mission to Mars” at the Victorian Space Science Education Centre (Melbourne) [1] and “Astrobiology in Secondary Classrooms” (ASC), a program carried out over three years in eight U.S. locations [2].

Faculty members of the University of Rome Tor Vergata began working in 2004 on out-of-school programs for undergraduate students attending nearby schools, in the frame of an educational project, known as *Piano Lauree Scientifiche* (PLS, National Plan for Scientific Degrees), supported by the Italian Ministry of Instruction, University and Research. The PLS rationale stems from the awareness that in recent decades it has been detected in Italy a decrease in enrollment in basic sciences [3, 4]. The PLS strategy is based in making the University's laboratories and research staff available to students, so as to give the latter a practical scientific experience and making them more disposed to study scientific disciplines at school, and perhaps pursue further scientific studies at the university (<http://www.progettolaureescientifiche.eu>).

Starting from fall 2011/12 an initiation to astrobiology concepts has been included in the PLS's activities at the University of Rome Tor Vergata. This not only because astrobiology touches an emotive part of our intellect and awakens our need for exploration, but also because as this field is rapidly evolving, it is important to develop an up-to-date educational infrastructure for the next generation of astrobiologists [5].

In the PLS-Laboratory of Astrobiology the participation of high-school students has a voluntary basis, although also their performance at school is also taken into account. The key topic is the search for life around other stars focusing on our understanding of the nature and distribution of habitable planets beyond the Solar System and characterization of the observable ones. In addition, a focus on the potential of life to adapt to extreme Conditions on Earth is proposed as a scientific prerequisite for the search of life beyond Earth. The program of the PLS-Laboratory of

Astrobiology includes two lectures given at schools by the Faculty referent and four experiences at the University's laboratories. After the 2012 edition, the students presented a poster on the effects of space radiation on extremophiles at a Workshop held in Rome [6; [www.scienceperception.it/](http://www.scienceperception.it/)]. Whereas a few volunteers among the 25 students who attended the 2013 edition will give a talk on "Extremophilies in Space" during the European Researchers' Night 2014, which will be held in Frascati ([www.frascatiscienza.it/](http://www.frascatiscienza.it/)).

Building up on results of the PLS-Laboratory of Astrobiology, which appeared to raise the interest of students in science [7], an Astrobiology module was added to the 2010 edition of the *Stage a Tor Vergata* ("Internship at Tor Vergata"; [www.stageatorvergata.it](http://www.stageatorvergata.it)). This internship is an educational project, linked to the PLS, open to fifty students selected from various Italian schools who enter the University's laboratories for one-week, twice a year [8]. The key topic of the first Astrobiology module was the search for life around other stars and the students presented the attended activity during an event organized by the University for ten nearby schools.

In the 2014 edition of the *Stage a Tor Vergata* the Astrobiology module was proposed as a "hands-on" approach by taking advantage of the participation of the University Tor Vergata in two experiments to be carried out on the International Space Station (ISS). The working hypothesis was that exposing pupils to laboratory practice in astrobiology cutting-edge experiments would be a strong motivator for the study of science and would raise their interest in astrobiology.

The proposed experiments are part of two proposals selected by the European Space Agency (ESA) for the next EXPOSE-R2 mission: Biofilm Organisms Surfing Space (BOSS) and BIOlogy and Mars Experiment (BIOMEX). Within these projects, selected organisms will be exposed to space conditions (and Martian simulated conditions in space) aboard the ESA's EXPOSE-R2 facility [9] expected to be launched on the 23rd of July 2014, and after one month positioned outside the ISS during an extravehicular activity performed by astronauts. These experiments aim at addressing fundamental astrobiology questions dealing with the limits of life as we know it and with the identification of biosignatures for searching life on Mars [10-12]. In order to put the biological aspects in the proper astrophysical context and to let the students discover the interdisciplinary aspects of research in astrobiology, a full day of the internship was devoted to the concept of habitability and to the search for planets around other stars. The aim was to familiarize the students with techniques used to detect exoplanets and with software applications that simulated the output of real observations.

## Methodology

In the 2014 edition of *Stage a Tor Vergata* 50 students (17 to 18 years old) from schools located in Northern and Central Italy were selected by their science teachers on the basis their performance at school, curiosity and motivation. The involved schools were those which previously took part in PLS's out-of school activities at the University of Rome Tor Vergata. The selected students were asked to choose one module among "Astronomical Techniques for Solar Physics", "Optic Dispositives for Information and Communication Technology", "Astrobiology", "Forensic Anthropology" or "Communication and Science Outreach". Each module offers one-week internship, twice during the year, so that each student experiences 10 days at the University.

Nine students (4 female and 5 male) attended the astrobiology module. Each one-week-internship consisted of 6 hours of introductory courses (in the morning) aimed at giving the background needed for the "hands-on" approach and of 15 hours in the laboratory (in the afternoon). Three days were devoted to laboratory procedures to investigate the subcellular effects of space vacuum and ultraviolet radiation on cyanobacteria previously exposed to simulated space and Martian conditions at the DLR (Cologne) in preparation of the EXPOSE-R2 mission. Another day was dedicated to techniques used in recent years to detect exoplanets, by letting the students use software applications that simulated the output of real observations (e.g., those from the Kepler space telescope). On the last day, during a round table the students prepared a presentation on the astrobiology activities; the presentation was given during a public event organized by the University at the end of the week.

At the end of each one-week internship students were also asked to evaluate the program by indicating whether their *curricula* benefited from the integration of different scientific competences and whether they were satisfied with the experience. The results were further evaluated by comparing pre- and post- internship learning tests made of 30 multiple-choice questions with 3 possible answers.

## Results

The program allowed the students to dream and expand their collective scientific knowledge at the same time, doing "basic" biology and astrophysics experiments, and was therefore successful in captivating their minds and raising their interest in science and astrobiology.

Thanks to the “hands-on” approach, students experienced various molecular biology tools often described in school science textbooks, here applied to investigate the physical-chemical limits of life as we know it, and familiarized with techniques used in recent years to detect exoplanets.

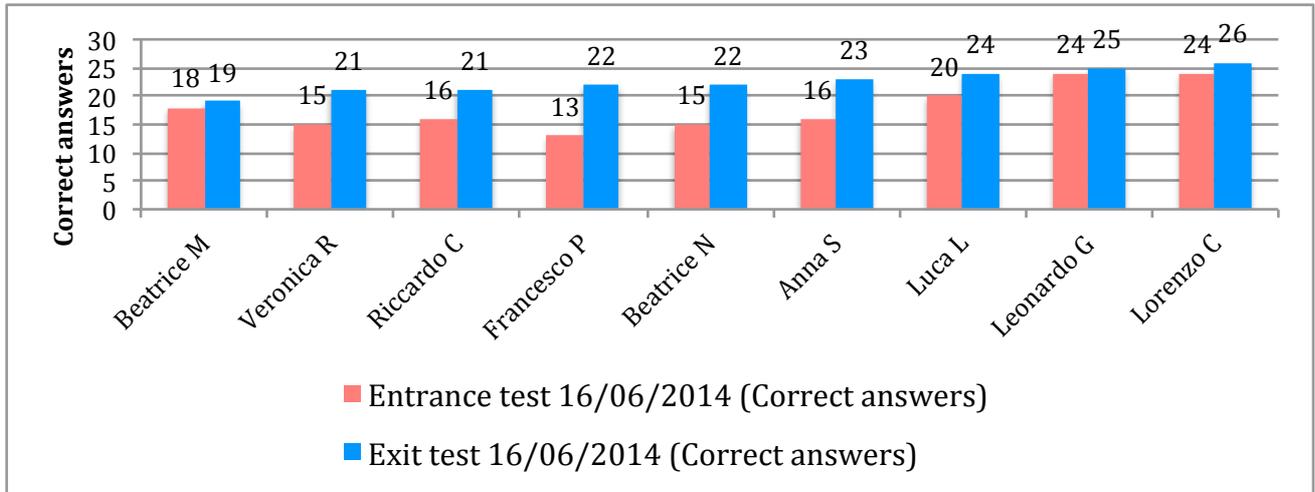
Students extracted genomic DNA and looked for DNA damage by using a PCR-based method, in a desert strain of the cyanobacterium previously exposed to ground-based space simulations in the frame of the EXPOSE-R2. The students’ perception of the cellular structures was refined through 3-D imaging of cyanobacteria with using a confocal laser scanning microscope. In addition, students familiarized with basic analysis techniques and capabilities to find candidate exoplanets from their signatures in stellar light curves and spectra. Each student worked on one planet (GJ667Cc, Kepler-62e, Kepler-283c, Kepler-296f, GJ667Cf, GJ163c, HD40307g, Kepler-61b or Kepler-186f) and assessed their potential habitability by comparing their physical features with those tolerated by terrestrial extremophiles.

Beside gaining scientific knowledge on the EXPOSE-R2 and KEPLER space missions, the students properly identified associated astrobiology tasks that might be of public interest, such as understanding the limit of life, searching for life beyond Earth and identifying our planet’s twin (not shown).

The analysis of the pre- and post- internship learning test pointed out that each student scored better after the internship at the questions dealing with theoretical aspect and scientific and technological applications addressed during the astrobiology module (Fig. 1), bringing the average of correct answer from 59,33 % to 78.66 %. The analysis by gender revealed that, on average, male students got higher scores than females in the post-internship learning test.

The proposed activities had a positive impact on all students, as revealed by the evaluation questionnaire (Fig. 2); no negative feedback was given when the students were asked about the utility of the proposed activities in the contest of their contact with the academic world.

There was no difference between the fraction of students agreeing with the statement “I would like to become an astrobiologist” before and after the internship (in each case, 3 out of 9).



**Figure 1: Pre- and post- internship learning tests made of 30 multiple-choice questions with 3 possible answers given by the students attending the astrobiology module of the *Stage a Tor Vergata***

Evaluation Questionnaire				
Male: 5		Female: 4		Class: Fourth year
	Definitely Not	No	Yes	Definitely Yes
Do you think the topics of the internship were interesting?			2	6
Was the task too difficult for you?	1		4	4
Do you think participating in this kind of initiative is useful for you?			1	7
Do you consider the contact with the academic world through initiatives of this kind is positive?			2	7
Do you think the teachers were understandable?			6	3
Do you understand all of the lessons?			7	2
Did you appreciate the lab activities?			6	3
Were your skills sufficient for following attending course?		4	4	1
Are the topics of the internship very different from those taught at your school?			5	4
Was the available scientific equipment suitable?				9
Do you think participating to the internship was worth?			1	8
Do you think the internship was positive?			2	7

**Figure 2: Evaluation questionnaire completed by the students at the end of the attending the astrobiology module of the *Stage a Tor Vergata***

## Discussion

The main goal of the reported “hands-on” project of the astrobiology module of the 2014 edition of *Stage a Tor Vergata* was to get students involved in space-related astrobiology experiments in order to expand the next generation of astrobiologists and, at the same time, to make them more prone to studying scientific disciplines at school, and perhaps pursue further scientific studies at the University. The strategy was to involve them in astrobiological researches aimed at addressing the question related to whether there is life beyond Earth. The approach was to make them consider that our understanding of life on exoplanets must be based on what we know about life on Earth and on the extremes it can tolerate. Hence, in the “hands-on” project the students investigated the endurance of an extreme-tolerant cyanobacterium, selected for the EXPOSE-R2 space mission, under ground-based simulations of space and Martian conditions. In addition, they familiarized with methods used by the astronomers to find exoplanets, focusing the transit method used by the Kepler space telescope, and to assess their habitability.

In the organizers’ opinion, the students adapted well to a scientific level of complexity that was far from that they experience at school. At the same time they increased their capability to reason scientifically, moving across the interdisciplinary science that is astrobiology. This was particularly evident during the last day round-table discussion, when they showed a high capability to reason scientifically about astrobiology issues.

Beside this, comparison of pre- and post- internship learning tests showed a significant gain in the student’s perceived knowledge of astrobiology. As pointed out by the evaluation questionnaire, this program was a successful initiative to take astrobiology beyond the typical university and research environments and share cutting-edge discoveries and unique perspectives with undergraduate students. All the students pointed out the topics of the internship were very different from those taught at their schools, appreciated the established contact with the academic world and considered as interesting the topics addressed during the “Astrobiology” module.

Students implemented their *curricula* with biology and physics multidisciplinary experience, thus getting one step ahead in integrating different area of knowledge and achieve an open, non-compartmentalized vision of science. This was pointed out during a public event organized by the University at the end of the stage, when they appeared confident in presenting the activities they were involved in to students from nearby schools.

Finally, thanks to this experience, the students were confronted to profound philosophical questions raised by the field of astrobiology, such as those about our place in the Universe and the

possibility of life beyond Earth, by using “simple” evidence given by the endurance of life as gathered from a desert cyanobacterium thriving in Mars analogues on Earth [13].

In conclusion, the out-of-school astrobiology activities conducted in last few years at the University of Rome Tor Vergata – and those planned to be performed in the coming years – will contribute to increase the number of motivated and talented students enrolling in scientific degrees and, hopefully, to increase the ranks of the Italian astrobiologists’ next generation.

**Acknowledgments.** Authors are grateful to the Italian Ministry of Instruction, University and Research for funding the Stage at Tor Vergata and to the Italian Space Agency for supporting the BOSS\_Cyano and BIOMEX\_Cyano projects. Thanks are due to Mickaël Baqué and Cyprien Verseux for their valuable help and to the students Lorenzo C, Luca L, Leonardo G, Beatrice M, Beatrice N, Riccardo C, Francesco P, Veronica R and Anna S, for attending with enthusiasm the 2014 edition of the Astrobiology activity. Thanks are also due to the students who attended the PLS-Laboratory of Astrobiology.

## References

- [1] Fergusson J, Oliver C, Walter MR (2012) Astrobiology outreach and the nature of science: the role of creativity. *Astrobiology* 12:1143-53.
- [2] Arino de la Rubia LS (2012) The Astrobiology in secondary classrooms (ASC) curriculum: focusing upon diverse students and teachers. *Astrobiology* 12:892-9.
- [3] Vittorio N (2010) Il Progetto Lauree Scientifiche 2005 – 2009. Sintesi delle attività e dei risultati a livello azionale *In* Workshop Vetrina PLS: da Progetto a Piano, Siena, Italy.
- [4] Montalbano V (2012) Fostering student enrollment in basic sciences: the case of Southern Tuscany. *In*: IMCIC'12, International Institute of Informatics and Systemics, editors: N. Calloas N et al. pp. 279-284.
- [5] Foster JS, Jennifer JC (2009) Astrobiology undergraduate education: students’ knowledge and perceptions of the Field. *Astrobiology* 9:325-33.
- [6] Moretti C (2013) Un'esperienza di Astrobiologia: la tenacia della vita nello spazio. *In*: Second Roma Workshop on Past and Present Perception of Science A century of research on cosmic rays and future perspective. April 19, Università RomaTre, Rome.
- [7] Billi D, Moretti C (2013) Laboratorio di astrobiologia: la ricerca di pianeti e di vita intorno alle stelle. *In*: Conference on the National Plan for scientific university degrees. December 12 -13, Città della Scienza, Naples.

- [8] Catena LM, Berrilli F, Davoli I, Prossposito P (2013) *Studenti-Ricercatori per Cinque Giorni. "Stage a Tor Vergata"*, Springer-Verlag, Italy.
- [9] Rabbow E, Rettberg P, Barczyk S, Bohmeier M, Parpart A, Panitz C, Horneck G, von Heise-Rotenburg R, Hoppenbrouwers T, Willnecker R, Baglioni P, Demets R, Dettmann J, Reitz G (2012) EXPOSE-E: an ESA astrobiology mission 1.5 years in space *Astrobiology* 12:374-86.
- [10] de Vera J-P, Boettger U, de la Torre R, Sánchez FJ, Grunow D, Schmitz N, Lange C, Hüber H-W, Billi D et al. (2012) Supporting Mars exploration: BIOMEX in Low Earth Orbit and further astrobiological studies on the Moon using Raman and PanCam technology. *Planetary and Space Science* 74:103–110.
- [11] Baqué M, Scalzi G, Rabbow E, Rettberg P, Billi D (2013) Biofilm and planktonic lifestyles differently support the resistance of the desert cyanobacterium *Chroococidiopsis* under space and Martian simulations. *Origin of Life and Evolution of Biospheres*, 43:377-389.
- [12] Baqué M, de Vera J-P, Rettberg P, Billi D (2013) The BOSS and BIOMEX space experiments on the EXPOSE-R2 mission: endurance of the desert cyanobacterium *Chroococidiopsis* under simulated space vacuum, Martian atmosphere, UVC radiation and temperature extremes. *Acta Astronautica* 91:180–186.
- [13] Smith HD, Baqué M, Duncan AG, Lloyd CR, McKay CP, Billi D (2014) Comparative analysis of cyanobacteria inhabiting rocks with different light transmittance in the Mojave Desert: a Mars terrestrial analogue. *International Journal of Astrobiology* 3:80.