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M Dwarfs, Super Earths and photosynthetic bacteria: a mix for laboratory studies

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The answer to one fundamental question of mankind, *Are we alone?*, is today closer than ever. The possibility to achieve this goal, is in fact supported by the fast developing in the highly interdisciplinary field of study of extrasolar planets. The observational data on extrasolar planets (more than 3500 discovered so far) show such striking properties (e.g. [9]) as well as the complexity of planet formation and evolution processes, that we are just starting to realize. Furthermore, a lot of new discoveries concern planets with Earth or pretty larger than Earth size (the so called Super Earths) close or inside the Habitable Zone (HZ, [6]) of their host star. Habitable planets are likely to exist not only around stars similar to the Sun, if current theories about terrestrial climate evolution are correct, but also around cooler stars like the M Dwarfs ones ([8]). For this reason, great observational efforts are ongoing, culminating today in the promising candidate in orbit of our closest star, Proxima Centauri ([1]), and the first habitable system, Trappist-1 ([5]), hosting at least two habitable planets out of seven rocky planets orbiting a small and very cool star (M8 spectral type). The distribution of extrasolar planets, discovered so far, shows a large number of low mass companions around M stars with an occurrence of 40% for stars that host planets with minimum mass between 3 and 30 $M_\oplus$, orbital periods shorter than 50 days ([7]), radii between those of the Earth and Neptune (1–3.8 $R_\oplus$). These high occurrence rates have a consequence: Super Earths represent the most common type of planetary systems in the Galaxy ([7]). Some of these planets O_2-rich atmospheres that lie within the HZ around their parent star are, in all probability, inhabited. The discovery and characterization of Earth-like planets with the eventual search for life is, arguably, one of the most exciting scientific endeavors of this decade. In this framework, it is critical to determine the types of biosignatures that we should be looking for when designing the next generation of ground- and space-based instruments that will observe these planets at high spectral and possibly spatial resolutions. The search for life signature requires the knowledge of planet atmospheres, main objective of future exoplanetary space explorations. Moreover, the recent finding of cyanobacteria able to use infrared light for oxygenic photosynthesis due to the synthesis of chlorophylls d and f, extending in vivo light absorption up to 750 nm respectively ([4]; [2]), suggests the possibility of exotic photosynthesis in planets around M stars. Knowing which pigments cyanobacteria can produce, when exposed to radiation sources expected for planets orbiting around M-dwarf stars, is relevant for future astronomical observations, such as those based on spectrometers mounted on large ground telescopes, like HARPS at ESO's La Silla Observatory, HARPS-N and GIARPS mounted on TNG in La Palma, or the forthcoming ESPRESSO spectrometer at the ESO's Very Large Telescope. Next generation satellites (JWST, ARIEL) are designed to detect exoplanet atmospheres. The proposed ARIEL telescope will observe in the spectral range where gases such as H_2O, CO_2, CH_4 NH_3, HCN, H_2S can be observed. To contribute to the current astrobiology challenges in searching for life elsewhere, our project will then focus on two crucial goals: 1) enhancing our knowledge of habitability, by investigating the adaptability of cyanobacteria to M-star environment with laboratory simulations; 2) mastering the use of spectroscopic remote-sensing of their atmospheric and surface reflectance biosignatures.

At the INAF – Astronomical Observatory, Department of Biology and CNR IFN LUXOR of Padova we are performing laboratory experiments [3] aiming at twofold results. At first we want to understand how photosynthetic biota, once present on an Earth-like planet orbiting in the habitable zone of a star of different spectral type than the sun, can modify its atmosphere. In particular we study how the O_2 – CO_2 balance would differ from the terrestrial one. An ancillary output is to understand if the feature of the "red edge" reflecting property and both the pigment composition and concentration of photosynthetic organisms would be influenced by the extended undergoing to a different radiation spectrum. Studying the different reflectance spectra of the pigments inside organisms grown in different light conditions allows to understand these biophysical properties. In these experiments we analyze the photosynthetic efficiency and gaseous productions of several strain of bacteria with a laboratory set up mimicking the exoplanetary surface temperature and radiation conditions. With this aim we developed a starlight simulator that reproduce the stellar spectrum in the wavelength range (365-940 nm) overlapping the photosynthetic active range (PAR) (280–850 nm).

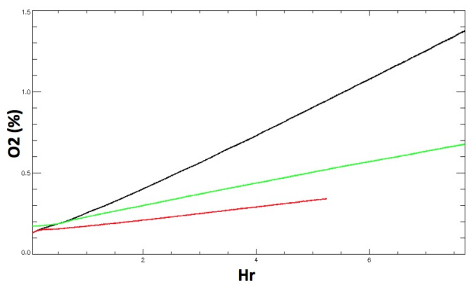

Figure 1: The oxigen production of a cyanobacteria species under simulated solar irradiation (black line) and M7 star simulated irradiation (red line). The green line is the oxigen production of a control organism irradiated with simulated solar light.

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