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Laboratory investigation on super-Earths atmospheres

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Abstract

In the framework of Atmosphere in a Test Tube, at the Astronomical Observatory of Padova (INAF) we are going to perform experiments aimed to understand the possible modification of the atmosphere by photosynthetic biota present on the planet surface. This goal can be achieved simulating M star planetary environmental conditions. The bacteria that are being studied are *Acaryochloris marina*, *Chroococcidiopsis spp.* and *Halomicronema hingdechloris*. Tests will be performed with LISA or MINI-LISA ambient simulator in the laboratory of the Padova Astronomic Observatory. In this paper we describe the whole road map to follow in order to perform experiments and to obtain useful data to be compared with the real ones that will be obtained by the future space missions. Starting by a fiducial experiment we will modify either environmental and thermodynamical properties in order to simulate both real irradiation by an M star and gas mixture mimicing super earths atmospheres. These laboratory tests could be used as a guideline in order to understand whether chemical disequilibrium of O_2, CO_2 and CH_4 could be ascribed to biotic life forms.

1. Introduction

In the next years new instruments will be available to the exoplanets search. Both on the ground based telescope and space based telescope. Another main aim of these new instruments (SPHERE, GPI, EPICS, ECHO, just to mention someone) will be the characterization of exoplanets dynamical and atmospheric characteristics. The latter will impose to have well known comparison spectra in order to identify the features of the observed spectra and correctly interpret the physical and chemical condition of the atmosphere observed. Normally with those aims synthetic spectra obtained by theoretical model are used. These synthetic spectra most of the times have difficulties to reproduce some characteristics of the observed spectra. For example one very difficult features to be reproduced by synthetic spectra are the condensation of components. The presence of condensation inside the atmosphere could modify the albedo and transmission of the atmosphere itself. A possible way to avoid these difficulties is to obtain true spectra of a gas mixture simulating the thermodynamical and chemical condition of the exoplanet atmosphere. This could be done using a environmental simulator which can control the temperature and the pressure of a mixture of gasses and this is what "Atmosphere in a Test Tube" (AMT_ITT) is going to do. AMT_ITT proposes to utilize the environmental simulator in order to create a database of spectra of exoplanet atmospheres simulated in laboratory with a full set of thermodynamical and chemical condition. The innovative concept of this work is to introduce living photosynthetic bacteria as one of the variables and to understand how their metabolic processes, in different irradiation conditions can affect the gaseous disequilibrium of the atmosphere. With the technical support of the Center of Study and Space Activity of Padua (CISAS) a simulator of Planetary environments called LISA and its small version called MINI-LISA were built in 2007 and they are now inside the INAF Astronomical Observatory of Padova laboratory. We are customizing them to perform our studies and step by step variate the main parameters (irradiation, temperature and gas concentration) to acquire the biota response to M star planetary conditions.

2. The environment simulator

The instrument that will be used to carry out the experiment is a custom version of LISA, a simulator of Planetary environments built with the technical support of the Center of Study and Space Activity of Padova (CISAS) and its small version called MINI-LISA. LISA has originally been created by the Astronomy Department of University of Padua to study Martian atmosphere. The main structure of the machine is a steel cylinder inside which are located six cells with a 250 cm^3 capacity. Inside the cells can be placed biological samples like bacteria, yeasts or microorganisms. Cells are connected with the outer part by pipes at the end of which are implemented mechanical filters to let the gas to course and at the same time avoid biological material to go through the pipes inside the cryostatic chamber located under them. MINI-LISA is a smaller version of LISA with only one cell to embed the bacteria. The idea behind MINI-LISA is to use a standard commercial dewar (from Oxford Instruments) modified it for our applications. As shown in figure 2 the reaction cell is isolated from the rest of the Dewar. This allow to evacuate the space between the cell and the dewar walls by the use of a vacuum turbo-pump. In figure 1a, b and c can be seen an overall sight of the instrument and the the image of one of the six cells located in it. The first experiments will be taken with terrestrial atmospheric chemical composition, solar spectrum irradiance and terrestrial atmospheric chemical composition, to have a first touchstone of data. Then will be made measurements varying the irradiation and using an M star-type simulator. The last measures will be kept with M star irradiation and exo-earth atmospheres.The measurements of gas inside the cells will be achieved thanks to a Raman type spectrometer.

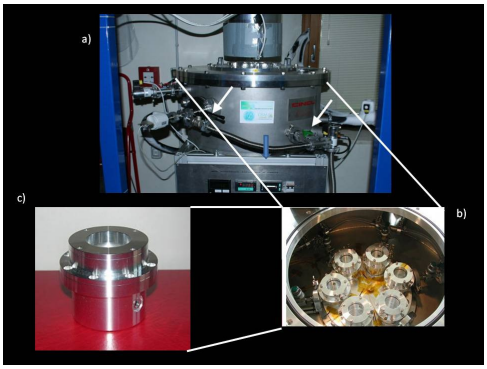

Figure 1: In the picture can be seen the instrumental complex in toto (a) and the particular of one of the six cells located inside it (b, c).

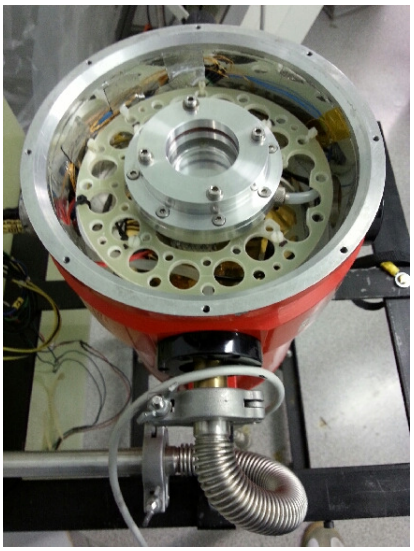

Figure 2: In the picture can be seen the instrumental complex of MINILISA