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PSS: Photochemistry on the Space Station. A low Earth orbit laboratory for astrochemistry and astrobiology outside the International Space Station

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Abstract

PSS (Photochemistry on the Space Station) will be the next European low Earth orbit experiment dealing with astrochemistry and astrobiology. A series of organic compounds and mixtures, in the solid and in the gas phase, will be exposed to the space environment.

1. Introduction

Solar UV radiation is a major source of energy for initiating chemical evolution towards complex organic structures, but it can also photodissociate even the most complex molecules. Thus, solar UV can erase the organic traces of past life at the surface of planets, such as Mars [1], destroy organic molecules present on meteorites and micrometeorites [2], influence the production of distributed sources in comets [3] or initiate chemistry in Titan's atmosphere [4]. In the interstellar medium, the UV radiation field emitted by stars in the galaxy is also responsible for the chemical evolution and the extraordinary diversity of organic molecules detected.

PSS (Photochemistry on the Space Station) is a new low Earth orbit (LEO) experiment, planned for launch in 2014, to improve our knowledge of the chemical nature and evolution of organic molecules with astrobiological implications in space environments. This is a new step in a series of experiments conducted outside the MIR space station, in the ESA BIOPAN and EXPOSE facilities, and in the NASA O/OREO nanosatellite [2, 5-10]. In PSS, both vented and sealed cells will be used allowing exposure of both solid and gaseous samples. Five kinds of experiments will be carried out exposing molecules related to different environmental factors of astrobiological significance: the interstellar medium, comets & meteorites, Titan, Mars, as well as a set of samples to test the stability of biochips in space. The exposure period will be approximately 18 months.

2. Photochemistry on the International Space Station

Photochemistry plays a leading role in the chemical evolution of organic matter in the Solar System and in the interstellar medium, specifically in the VUV domain (vacuum ultra violet- $\lambda < 200$nm). For this reason, laboratory studies of the photolysis of organic compounds related to astrophysical environments are common and different kinds of UV sources are used, e.g. monochromatic (e.g. H_2/He (122 nm), Xe (147 nm), CH_4/He (193 nm) [11] or simulating a wider range of UV (e.g. H_2 (122 nm and 160 nm) or deuterium discharge lamp (190 - 400 nm) [12], high pressure xenon lamps (190 - 400 nm) [13]. However, it is not possible to simulate accurately the whole range of wavelengths corresponding to the most energetic part of solar radiation below 200 nm [14], therefore results obtained in the laboratory are extremely difficult to extrapolate to space environments [8]. UV light reaching low Earth orbit (at the altitude of the International Space Station) is unfiltered. Thus, many samples can be exposed simultaneously in space experiments where photolysis is direct across the real solar UV spectrum and where the measurements can be easily extrapolated to various astrophysical environments. Moreover, the simulation of cosmic particles in addition to UV photons requires additional tools (ion and electron guns) and increases the complexity of ground experiments. Therefore, space is a unique laboratory allowing the exposure of samples simultaneously to all space parameters as well as the irradiation of the samples under identical conditions.

3. Hardware and samples

The molecules selected for measuring their stability in space conditions are of different exobiological and general astrochemistry interest and include: nitrogenous bases (adenine, guanine, xanthine, hypoxanthine), amino acids (glycine, amino isobutyric acid…), polycyclic aromatic hydrocarbons (PAHs), and organic residues synthesized during laboratory irradiation of icy mixtures simulating interstellar and cometary ices. Carboxylic acids will also be selected for Mars-relevant' research. They will be exposed either in pure form, or mixed with a Mars soil analogue. Thanks to closed cells, gaseous mixtures simulating the atmosphere of Titan (N_2 & CH_4) will also be exposed. Biochips will also be tested versus exposure to cosmic rays. Their complex bio-organic structures could be used as detectors for specific organic compounds on Mars and are being developed for future exploration missions [15]. Their survival during space travel will then be tested.

The LEO results will be compared with laboratory simulations to determine the differences between laboratory and space experiments and to attempt to improve laboratory sources.

The hardware for the PSS experiment will be presented and the improvements compared to previous LEO experiments will be discussed. The future of LEO facilities will also be discussed.

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