The BIOMEX experiment on-board the International Space Station: limits of life and detection of biomarkers after exposure to space- and to Mars-like conditions

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Abstract

As part of the Biology and Mars Experiment (BIOMEX; ILSRA 2009-0834), samples of the lichen *Circinaria gyrosa* were placed on the exposure platform EXPOSE-R2, on the International Space Station (ISS) and exposed to space or to a Mars-simulated environment for 18 months (2014–2016) to study: a) resistance to space and Mars-like conditions, and b) biomarkers for use in future space missions (Exo-Mars). When the experiment returned (June 2016), initial analysis showed rapid recovery of photosystem II (PSII) activity in the samples exposed exclusively to space vacuum and Mars-like atmosphere. Significantly reduced recovery levels were observed in Sun-exposed samples, and electron and fluorescence microscopy (TEM and FESEM) data indicated that this was attributable to the combined effects of space radiation and space vacuum, as unirradiated samples exhibited less marked morphological changes compared to Sun-exposed samples. PCR analyses confirmed that there was DNA damage in lichen exposed to harsh space and Mars-like environmental conditions, with UV radiation combined with space vacuum causing the most damage. These findings contribute to the characterization of space- and Mars-resistant organisms relevant to Mars habitability .

Introduction

To explore the limits of terrestrial life in space, we have to understand the effects of the space environment on unprotected biological and chemical material, and on the degradation of organic molecules or biomarkers. The EXPOSE-R2 (Fig. 1) on the ISS was a suitable facility for the exposure of samples of the astrobiological model lichen *Circinaria gyrosa*, part of the BIOMEX experiment (Biology and Mars Experiment, European Space Agency ESA). During 18 months (2014-2016), the lichens lived in a latent state at space and at simulated Mars-like conditions, to study Mars' habitability and resistance to space conditions. After return of the samples in June 2016, initial analysis showed rapid recovery of photosystem II activity in the samples exposed exclusively to space vacuum and to Mars-like atmosphere. In contrast, the samples directly exposed to solar UV radiation showed a slow and a lower recovery, in reference to their observed original activity. This tendency was corroborated with the complementary morphological/ultrastructural and biomolecular analyses [1]. Biomolecular analyses (PCR and sequencing) also revealed that the viability of *C. gyrosa* exposed to space conditions decreased in comparison to those exposed to the Mars-like environment [2]. Complementary, biogeochemical variations have been examined with Raman spectroscopy to assess the possible degradation of cell surfaces and pigments which were in contact with terrestrial rocks, and Martian analogue regolith. Identification of the biomarker whewellite (calcium oxalate) [3, 4] and other organic compounds and mineral products of the biological activity of *Circinaria gyrosa* were detected by Raman Laser. These findings contribute to answer questions on the habitability of Mars, the likelihood of the Lithopanspermia Hypothesis, the capability to detect biomolecules exposed to an extraterrestrial environment by life-detection instruments, and will be relevant for planetary protection issues.

Figure 1. *The Expose-R2 facility on the International Space Station with the experiment BIOMEX* ***Copyright*** *Roscosmos*

References

[1] de la Torre, R., Miller, A.Z., Cubero, B. Rabbow, E., Meessen, J., Sancho, L.G., de Vera, J.P. (2016) Survival of lichens on the ISS: preliminary results of Circinaria gyrosa as part of the BIOMEX Experiment..16th *EANA Astrobiology Conference.* Athens, Greece.

[2] Sanchez, F.J., E. Mateo-Martí, J. Raggio, J. Meessen, J. Martinez-Frias, L. Gª Sancho, S. Ott and R. de la Torre (2012) The resistance of the lichen *Circinaria gyrosa* (nom. provis.) towards simulated Mars conditions - a model test for the survival capacity of an eukaryotic extremophyle. Planetary and Space Science 72, 102-110.

[3] de Vera JP and the BIOMEX-Team (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 (1), Seiten 103-110. Elsevier. DOI:10.1016/j.pss.2012.06.010.

[4] U. Böttger, J. Meessen, J. Martinez-Frias, H.-W. Hübers, F. Rull, F. J. Sánchez, R. de la Torre, J.P. de Vera (2013) Raman Spectroscopic Analysis of the Calcium Oxalate Producing Extremotolerant Lichen Circinaria gyrosa. ***International Journal of Astrobiology*** 00 1–14.