Study of the degradation of biosignatures under Martian irradiation

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Mission

During its first billion years of existence, Mars was habitable, with the presence of liquid water on its surface in particular [1]. Then, during the Hesperian, the environmental conditions began to change: the atmospheric pressure decreased, leading to the loss of surface liquid water. Nowadays, if live could still be possible in deep aquifers, the surface of Mars is mostly incompatible with active live. On the other hand, in the absence of plate tectonics, ancient rocks are still present at the surface of Mars, some of them potentially containing microbial remains. Among the potential biosignatures that could be associated with such remains are microbialites, kerogenous microfossils and organic molecules. The rover of the NASA Mars 2020 mission is presently searching for such evidences in the Jezero crater. It also collects samples taken at the surface to be sent back to the Earth during the 2030's with the aim to search for ancient (and possibly recent) biosignatures using high-resolution laboratory instruments.

However, in the absence of magnetic field, and due to the low-pressure atmosphere, the surface of Mars is irradiated by Solar Energetic Particles (SEP) and Galactic Cosmic Rays (GCR) that could penetrate the subsurface up to several meters deep and degrade organic molecules and potential biosignatures with time. In order to increase the chance of detecting traces of life and/or prebiotic molecules, the rover of the future ESA mission ExoMars is equipped with a drill capable to collect samples up to two meters deep.

The objective of this thesis is to evaluate the effect of this irradiation during several billion years on fossiliferous Mars analogue rocks and the protective effect of different minerals on molecular biosignatures. This is highly relevant for the ExoMars mission in order to estimate the depth at which various biosignatures of interest may be preserved. More broadly, irradiation can also alter minerals, leading to an increase in the fluorescence background of their Raman signal and thus making their correct identification difficult. This effect will also be studied.

Analogue samples from the ISAR collection of Orléans will be used and specific samples made of minerals and biomolecules will be prepared. A specific focus will be made on hydrothermal samples since, on Earth, hydrothermal environments are considered as good places for the origin of life and for its early evolution [2]. Evaporitic salt deposits and silica sinters characteristic of such environments are also known to trap and preserve microbial remains. These materials are thus important targets for the search for life on Mars [3]. These samples will be exposed to proton irradiation at the CEMHTI Pelletron, CNRS, Orléans. The Pelletron is a light ions electrostatic accelerator capable to accelerate protons up to 3 MeV at a flux of about 3.10^10 protons/cm²/s. Which such a flux it is thus possible to reproduce several billion years of Martian irradiation in a few hours. In addition, in the framework of the GéoµPal/Astrobiology Project of Photonic and Ionic Martian Irradiation in the Laboratory (APPIMIL) supported by CNES, the team recently developed a unique Raman spectrometer permitting to monitor the changes occurring within the sample in situ during the irradiation [4]. First experiments carried out on different molecules and minerals are very conclusive and have already been presented in several conferences (e.g. [5]). A paper is also in preparation and will be submitted before the end of 2024.

Working at CEMHTI, the PhD student will have a direct access to the accelerator. He/she will select and prepare the samples to be irradiated, carry out the irradiation experiments, make the in situ and ex situ sample characterization and process the data. In particular, the student will have access to different ion beam analyses techniques at Pelletron (PIXE, NRA and RBS in particular), to high resolution Raman spectrometers, to Atomic Force Microscopes and to electron microscopes, among other. A large part of the work will also be devoted to numerical simulations in order to better simulate Mars irradiation and to improve the validity of the laboratory experiments.

Collaborations with different partners in France and in Europe during the project will permit to obtain complementary relevant samples and to carry out additional irradiation experiments in different conditions. More importantly, the student will work with the scientific team of the ExoMars mission and will proposed irradiated analogue samples to be analyzed with the flight spare models of the instruments.

References:

[1] F. Westall et al. (2015) Astrobiology 15:11, 998-1029.

[2] F. Westall et al. (2018) Astrobiology 18:3, 259-293.

[3] F. Westall et al. (2021) Int. J. Astrobio. 20:6, 377-393.

[4] A. Canizarès et al. (2022). App. Spec. 76:6, 723-729

[5] F. Foucher et al. (2023) IBA&PIXE conference, Japan, Abst. 12p-8.

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For more Information about the topics and the co-financial partner (found by the lab !);

contact Directeur de thèse - frederic.foucher@cnrs.fr

Then, prepare a resume, a recent transcript and a reference letter from your M2 supervisor/ engineering school director and you will be ready to apply online before March 15th, 2024 Midnight Paris time !

Profil

Physics/Astrobiology

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Message from PhD

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