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Raman spectroscopy study of the degradation of astrobiological materials under simulated Martian particle irradiation

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More than 3.5 billion years ago, the surface of Mars experienced habitable conditions compatible with the presence of liquid water, thus prompting the hypothesis that primitive microbial life may have appeared and developed at that time. In the absence of plate tectonics, ancient mineral and/or organic biosignatures may still be present at the surface of the red planet [1,2]. To detect such putative biosignatures, the current NASA Mars 2020 and future ESA ExoMars rovers, are equipped with Raman spectrometers capable of analysing both organic and mineral phases [3-5].

Nevertheless, the surface of Mars has been continuously exposed to high-energy UV radiation (down to 190 nm wavelength), deleterious for organics [1,6]. Moreover, in the absence of a magnetic field, it is also exposed to the solar and galactic cosmic rays that reach the surface and the near subsurface [7]. In addition to making the surface of Mars presently highly inhospitable, this radiative environment may have altered putative biosignatures over time. The European Space Agency's ExoMars mission, now scheduled for 2028, will therefore explore the subsurface of Mars, down to 2 m deep, in order to increase the chances of detecting well preserved molecules.

In order to evaluate the effect of particle irradiation, we irradiated molecules of exobiological interest, mixed with or protected by analogous mineral matrices from Mars, with 2.8 MeV protons on the Pelletron of the CEMHTI laboratory at the CNRS in Orléans. In particular, we developed a new device called RAMSESS (for RAMan SpEctroscopy for in Situ Studies), to study the changes in the Raman signal of different minerals and organic molecules in situ within the irradiation chamber [8]. The objective was to estimate the depth at which molecules are likely to be detected on Mars, in particular by Raman spectroscopy.

We have proposed a model to compare the dose received by the samples during irradiation at Pelletron with that received on Mars, with depth and time. The RAMSESS system allowed us to follow the evolution of different minerals and molecules. Interestingly, we observed a strong difference between the irradiations carried out on pellets produced from pulverulent samples and those carried out on single crystals. These results are relevant in the framework of the ExoMars mission and are very complementary to those obtained during the BIOMEX experiment on-board the ISS [9,10].

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