Detection of Biosignatures on Mars Using Raman Spectroscopy

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Raman spectroscopy is sensitive to organic and mineral phases. This method is thus highly suitable for the detection of biosignatures associated with active and ancient traces of life [1] and thus extremely useful in the context of current and future missions to Mars (Mars 2020, ExoMars and Mars Sample Return) [2,3].

In particular, Raman spectroscopy is very sensitive to pigments, such as carotenoids [4,5], and to kerogen (i.e., insoluble carbonaceous matter of biological origin) [5-7]. In ancient terrestrial rocks, this detection is greatly facilitated by the Raman micro-imaging method consisting in scanning the sample (usually a petrographic thin section) while acquiring Raman spectra, in order to visualize the spatial distributions of the different phases [8]. Unfortunately, sample preparation systems and Raman spectrometers on-board Martian rovers are limited compared to laboratory systems. In particular, microscopy imaging in transmitted light and high-resolution Raman mapping is not possible in the absence of a thin section preparation device [9]. Although in situ Raman spectrometers have been developed to maximize their capabilities according to mission specifications [2,3,10,11], it will still be difficult to detect such biosignatures in situ on Mars.

Moreover, the surface of Mars has been continuously exposed to high-energy UV radiation, solar energetic particles and galactic cosmic rays [12,13]. In addition to making the surface of the planet presently inhospitable, this radiative environment may have altered putative biosignatures over time. Therefore, the ESA/NASA ExoMars mission, now scheduled for a launch in 2028, will explore the subsurface of Mars down to 2 m deep, in order to increase the chances of detecting well preserved organic molecules.

In order to evaluate the effect of particle irradiation on the Raman signal of biosignatures, we developed a new device, called RAMSESS (for RAMan SpEctroscopy for in Situ Studies, Fig.1A), to study the changes in the Raman signal of specific molecules and materials, in situ within the irradiation chamber of Pelletron ion accelerator at CEMHTI laboratory, CNRS, Orléans, France [14,15]. Using models, we were able to compare the dose received by the samples during irradiation in the laboratory with that received on Mars, and to evaluate the alteration of the Raman signal of beta-carotene in the first 2 meters under the surface of Mars after up to several billion years of irradiation (Fig.1B) [15]. We thus showed that beta-carotene could theoretically be detected at Oxya Planum, in the drill cores that will be collected during the future ExoMars mission.

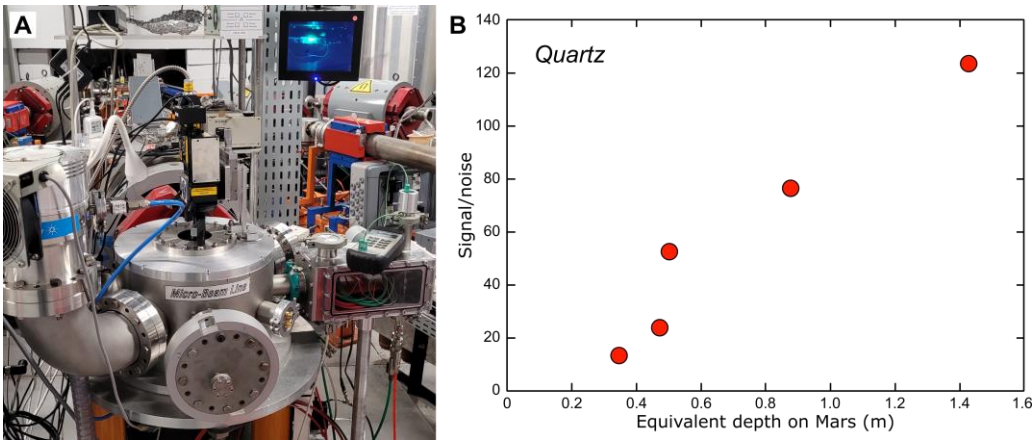

Fig. 1. (A) The RAMSESS device used to make Raman spectroscopy in situ during irradiation experiment at the Pelletron facility, Orléans, France. (B) Raman signal to noise ratio of the 1515 cm^{-1} Raman band of beta-carotene versus the equivalent depth on Mars after 3.5 Ga of irradiation under a quartz layer.

Similar experiments will be carried out to assess the effects of radiation on other types of samples and biomolecules.

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