PhD thesis (3 years) – Development of Supercritical Fluid Extraction of extraterrestrial organic matter: meteorites and Martian analogues

Background

The analysis and identification of organic matter inside extraterrestrial samples is one of the main goals in astrobiology. In the past decade, numerous extraterrestrial bodies have been studied during missions or thanks to telescope observations and some of them showed a variety of organic molecules. However, the extraction of organic matter from such a complex environment is often difficult and considered as an analytical lock. Indeed, it can be linked to a mineral matrix and in small quantity which complicates the extraction and consequently the detection and following characterisation.

Currently, the extraction of organic matter from complex matrices (as the extraterrestrial ones) are usually carried out by long multi-steps liquid-solid extractions (and purification). Supercritical fluid extraction (SFE) is a technique that strongly developed those past 10 years. The yields of extraction are equal to better than with other usual techniques while it is fast, greatly limits the risk of contamination and does not need complex manipulation of the sample. Contamination is one of the major issues in the study of extraterrestrial organic matter, therefore this technique seems particularly adapted as first step for these precious samples study. Although SFE is commonly used in various fields as environment, it was rarely used in astrochemistry[1,2]. Each type of sample needs the optimisation of many parameters: pressure, temperature, co-solvents… This optimisation can be carried out with the help of experimental design [3] and thanks to experiments of extraterrestrial analogues. The SFERE project aims to develop supercritical fluid extraction of extraterrestrial organic matter for sample return as first objective. The first step will be to prove the efficiency of this technique on extraterrestrial objects already gathered on Earth and showing a sufficient quantity of organic matter for the extraction: carbonaceous chondritic meteorites[4]. The second step will be the extraction of Martian soil analogues, in the prospect of samples returning from Mars with the MSR mission in about 10 years.

Project

This PhD thesis is funded by an ANR JCJC as part of the SFERE project. The student will have to participate to the development of the extraterrestrial organic matter extraction using supercritical fluids on meteorites and Martian analogues.

The PhD will process in two phases. First the optimisation of the supercritical fluid extraction of carbonaceous chondrites organic matter will be carried out. This work will need the creation of an appropriate experimental design previous to the experiments. The creation of this experimental design will be carried out by a research engineer that will work in collaboration with the PhD student, based on Devièse et al. study in 2018 [3]. It will enable to reduce the number of experiments in order to optimise the numerous parameters of SFE. Consequently, the first step for the PhD student will be to choose an appropriate analogue for the meteorites. Then the experiments will be carried out on the newly acquired SFE and the extract analysed at LISA by GC-MS. Thereafter, data treatment will be necessary to find the optimised parameters for the extraction of carbonaceous chondrites. In order to validate the optimisation, the extraction yields will be compared to usual techniques of extraction: Soxhlet, ASE and sonification. Finally, the last step will be the extraction of meteorite samples already in the LISA's collections: Murchison, Aguas Zarcas and Mukundpura. Specific attention will be given to the apparition of buy-products at each step of the process.

The second phase of the PhD will focus on the extraction of Martian soil samples. The same steps, identical to the first phase, will be developed with a higher autonomy from the PhD student. This phase

is very important as samples should be returned from Mars in the 30/40ies and SFE could become the favorite technique if the optimisation proves to be satisfactory.
The PhD student will also make the first test of SFE-SFC(supercritical fluid chromatography)-MS coupling on this type of samples with a specific attention toward the choice of column in order to study the chirality of the molecules.

The PhD student could participate to the RED, a school by the Astrobiology French Society, in order to get a larger knowledge on astrobiology. The results will have to be presented during national and international congresses and will lead to publications.

Requirements

- Master's degree or equivalent in (analytical) chemistry
- Experience in extraction with one or several techniques
- Experience in analysis by GC-MS
- A strong motivation and good team work abilities
- A good oral and written communication skills in English

Additional experience

- Knowledge of experimental design
- Experience in SFE
- Interest for outreach and mediation
- Interest for space

Laboratory

You will be part of the "Astrochemistry and astrobiology" team inside the Laboratoire InterUniversitaire des Systèmes Atmosphérique (LISA). The LISA has a strong expertise in the development of space instrumentation, is recognised at the international level and participates to numerous space missions (Curiosity, ExoMars, Rosetta…).
The SFE-SFC-MS instrument should be received during the first semester of the 2024-2025 university year, in the new laboratories inside the Science and Technologies faculty of Paris-Est Créteil University. The laboratory is easily accessible by metro line 8 and RER D from Paris.

How to apply

All interested candidate must contact the supervisors before the 16th of June for supplementary information and apply with a CV (including 2 referees), a cover letter and a reference letter.
- Clara Azémard (clara.azemard@lisa.ipsl.fr)
- Fabien Stalport (fabien.stalport@lisa.ipsl.fr)
- Hervé Cottin (herve.cottin@lisa.ipsl.fr)
Starting date is 1st of October 2024.

Bibliography

1. Abrahamsson, V., Henderson, B. L., Zhong, F., Lin, Y. & Kanik, I. Online supercritical fluid extraction and chromatography of biomarkers analysis in aqueous samples for in situ planetary applications. *Anal. Bioanal. Chem.* **411**, 8091–8101 (2019).
2. Menlyadiev, M., Henderson, B. L., Zhong, F., Lin, Y. & Kanik, I. Extraction of amino acids using supercritical carbon dioxide for in situ astrobiological applications. *Int. J. Astrobiol.* **18**, 102–111 (2019).
3. Devièse, T. *et al.* Supercritical Fluids for Higher Extraction Yields of Lipids from Archeological Ceramics. *Anal. Chem.* **90**, 2420–2424 (2018).
4. Sephton, M. A. Organic compounds in carbonaceous meteorites. *Nat. Prod. Rep.* **19**, 292–311 (2002).