**Physico-chemical and structural transformations under shock conditions of hydrated minerals and application to water transport by meteorite impacts**

**Context:**

Very high-speed or hypervelocity impacts (Hyper Velocity Impact, HVI) are impacts characterized by speeds ranging between 8 and 70 km/s which induce shock waves of very high pressures (up to 100 GPa). In geoscience, hypervelocity impacts are at the heart of emblematic questions linked, for example, to giant impacts such as the one between the Earth and a Mars size object. This late would have led to the formation of the Moon and modified the evolution of our planet. What are the associated chemical, mineralogical and organic balances? Can the presence of water on Earth, which is located in a dry region of the solar system, be explained by meteorite impact, as suggested by the recent detection of molecular water in lunar craters [Honnibal2020, Daly2018].

Until now, a main obstacle to scientific advances in these fields was the impossibility of reproducing, in a controlled and instrumented way, laboratory tests in the high-speed range (8-70Km/s). On Earth, one of the ways to reproduce equivalent thermomechanical loading is based on laser shock. The analogy between HVI and laser-induced shocks was proposed by Pirri [Pirri 1977]. When a high-intensity laser (ns, 100-1000J) is focused on the surface of a material, a very hot and high-pressure plasma (1-100 GPa) is produced. By reaction to its relaxation, a shock wave propagates into the material. In recent years, new laser technologies have made possible to shape temporally (1-100ns) and spatially (focal spot diameter 0.2-5mm) laser pulses and thus reproduce pressure loading equivalent to projectile impacts [Thesis B. Aubert 2018].

The major advantage in using lasers is that they enable extending the ranges of studied impact velocities but also to benefit from in-situ and in-operando instrumentation. Additionally, samples can be retrieved for post-mortem analysis. The challenge of this thesis will consist in taking advantage of these new experimental developments to study the transport of water during meteorite impacts.

**Objective of the thesis - What happens to the water contained in hydrated minerals during the shock experience and what is the overall water transfer after the shock? How does the water content influence the behavior of those materials under impact?**

This thesis subject will consist in studying the fate of water contained in hydrated minerals under hypervelocity impact conditions. The methodology, to be developed for this study, will be established by studying silica, a material already referenced under shock [Thesis C. Dereure 2019]. We will focus here on the evolution of the density of materials and the variations in their hydration rate. The thesis will consist of:

- Analysis of samples before and after shock experiment: characterization of hydration and collection of debris (Raman and Infrared Spectroscopy, Scanning Electron Microscopy (SEM and TEM) and X-ray diffraction at IPR and IMPMC)

- Hyper-velocity impact experiments on various national and international facilities, equipped with in-situ diagnostics such as VISAR, shadowgraphy, X-ray diffraction and X-ray absorption at launchers, HERA and LULI2000 lasers, ESRF synchrotron, EuXFEL or SACLA free-electron lasers).

**Required skills:**

The candidate must have a bac+5 level (master degree or equivalent) in one of the following fields:

* Materials science
* Physico-chemistry
* Condensed Matter Physics

Skills required among the following:

* Curiosity and interest in multi-disciplinarity science
* Rigor and spirit of synthesis
* Sense of organization
* Communication skills and ability to work in a team
* Autonomy at work

Would be a plus:

* Knowledge of shock mechanics
* Knowledge of one or more of the following analysis techniques: IR spectroscopy, Raman spectroscopy, X-ray diffraction, X-ray absorption, electron microscopy.
* Mastery of the Python language
* Good level of written and spoken English,

**Funding:**

The candidate will join the IPR's "Dynamique Choc Impact" team within the mechanics and glasses department and this project is part of the ANR SICLAMEN carried out by the IPR, IMPMC, CEA and LULI laboratories. <https://anr.fr/Projet-ANR-22-CE08-0010>

Possibility of teaching assignments (max 64 hours of teaching per year in training courses at the University of Rennes)

**Management:**

Jean-Pierre Guin, Didier Loison (IPR - University of Rennes)

Marion Harmand (IMPMC - Sorbonne University)

**Place of thesis:** IPR -University of Rennes, Campus de Beaulieu

**Start of the thesis:** October 1, 2023

**For further information:** send an email to [didier.loison@univ-rennes.fr](mailto:didier.loison@univ-rennes.fr), [Jean-pierre.guin@univ-rennes.fr](mailto:Jean-pierre.guin@univ-rennes.fr), [marion.harmand@cnrs.fr](mailto:marion.harmand@cnrs.fr)

**To apply:** complete the application form on the S3M “Science de la Matière, Molécule et Matériaux” doctoral school website among the subjects of the IPR: UMR 6251 - INSTITUT DE PHYSIQUE DE RENNES

<https://theses.doctorat-bretagneloire.fr/s3m/campagne-2023>

The file must contain a single document including

* A detailed curriculum vitae
* A cover letter
* A copy of the Master 1 and Master 2 scores (1st semester) with indication on the ranking (if known)

**Application deadline: June 16, 2023**