ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: Volatile Element Behavior and Isotopic Fractionation in Early Planetary Differentiation: Insights from Iron Meteorites

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Host lab/ Team: ***CAGE-IPGP-UMR7154***

Financing: Doctoral contract with or without teaching assignment-HERMES Labex Program

Presentation of the subject:

The origin and behavior of volatile elements during the early stages of planet formation remain central questions in planetary science. Traditionally, studies have focused on undifferentiated meteorites (chondrites) or planetary crusts. However, recent discoveries suggest that iron meteorites—remnants of the metallic cores of the first differentiated planetesimals—are among the oldest planetary materials and offer a unique perspective on volatile element behavior.

This PhD project aims to systematically investigate the isotopic fractionation of Germanium (Ge), gallium (Ga), and sulfur (S) in iron meteorites to constrain the mechanisms driving volatile depletion during early planetary differentiation. These elements, with their siderophile and chalcophile affinities, can provide critical new insights into both nebular and planetary-scale processes.

Objectives:

- Measure concentrations and isotopic compositions of Ge, Ga, and S in a representative suite of iron meteorites.
- Quantify isotopic fractionation during metal–sulfide partitioning and evaporation through controlled laboratory experiments.
- Distinguish between volatile loss due to nebular processes (pre-accretion) and planetary processes (e.g., core formation, impact-driven evaporation).
- Refine models for the origin of volatile element abundances in Earth and other terrestrial planets.

Methodology:
The project will integrate cutting-edge approaches:

- **Sample Analysis:** Preparation of meteorite samples and isotopic measurements of Sb, Ga, and S using MC-ICPMS and IRMS techniques at IPGP.
- **Experimental Simulations:** High-temperature, redox-controlled evaporation experiments and high-pressure metal–silicate/sulfide partitioning experiments (using piston-cylinder presses and controlled atmosphere furnaces).
- **Data Interpretation:** Comparison of experimental results with natural sample data to model volatile depletion processes in early planetary bodies.

Research Environment:

This project will be hosted at IPGP (Institut de Physique du Globe de Paris) within a multidisciplinary team combining expertise in cosmochemistry, isotope geochemistry, and experimental petrology. The student will have access to unique analytical facilities for ultra-precise isotopic measurements and high-pressure, high-temperature experimentation.

Impact:
This research will generate the first systematic isotopic dataset for Ge, Ga, and S in iron meteorites, providing crucial insights into volatile element behavior during early Solar System evolution. It will also establish new experimental constraints on metal-silicate-sulfide interactions, with broad implications for understanding the volatile inventories of Earth and other terrestrial planets.