Master thesis proposal

Laboratoire Matière en Conditions Extrêmes (LMCE)
CEA, Campus TERATEC
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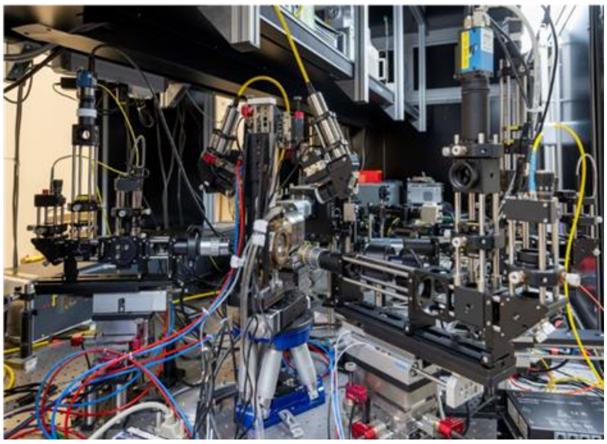
Title: Sound velocity measurements in CH_4 under extreme pressure and temperature conditions: validity of Birch's law for planetary interiors.

Scientific description:

Methane (CH_4) is a major component of the ice layers present in giant planets such as Uranus and Neptune. Understanding its behavior under extreme pressure and temperature conditions is crucial for refining models of the interiors of these planets. Specifically, the equation of state (P, V, T) of methane is key information. However, current data is limited and does not cover the pressure and temperature ranges representative of planetary interiors.

We have recently set up a spectroscopy platform that combines in-situ Brillouin and Raman measurements in a laser-heated or externally heated diamond anvil cell [1]. This setup (see Figure 1) allows us to study molecular systems under extreme conditions of pressure and temperature, corresponding to the internal conditions of giant planets (1-300 GPa, 300-6000 K). Brillouin spectroscopy, based on the interaction of light with acoustic waves in the sample, give access to the adiabatic sound velocity and the equations of state of these systems in the fluid phase. Raman spectroscopy allows to monitor molecular vibrational modes and thus detect phase transitions or chemical reactions occurring under extreme conditions.



The goal of this internship is to explore the phase diagram of fluid methane using Brillouin and Raman spectroscopy techniques. We will determine the stability domain of the CH_4 molecule and the conditions under which it dissociates into carbon (graphite or diamond) and hydrogen. Furthermore, it has been shown that at 300 K, the speed of sound in methane varies linearly with density, in accordance with Birch's law [2]. The internship aims to extend these measurements to high temperatures in order to track the evolution of methane's thermodynamic properties in the fluid phase. The data obtained will contribute to refining the planetary interior models of Uranus and Neptune and are expected to be published in an international scientific journal.

[1] A. Forestier, G. Weck, F. Datchi & P. Loubeyre, High Pressure Research, 42:3, 259-27 (2022).
[2] Dylan W. Meyer et al. Journal of Geophysical Research: Planets, 127, e2021JE007059 (2022).

Techniques/methods in use: Experiments in diamond anvil cells. Brillouin and Raman spectroscopies.
Applicant skills: Master's degree (M2) in condensed matter physics; strong interest for experimental physics.
"**Industrial partnership**: No
Internship supervisor(s) Gunnar Weck, Alexis Forestier (gunnar.weck@cea.fr; alexis.forestier@cea.fr)
Internship location: CEA/DAM Île-de-France, Campus TERATEC 91680 BRUYÈRES-LE-CHÂTEL
Possibility for a Doctoral thesis: Yes