SCIENCES SORBONNE UNIVERSITÉ

2021-2022

Master thesis proposal

IMPMC
Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie

Campus Pierre et Marie Curie
Tower 23 - 4th floor -23-22
Director: A. Marco Saitta

Title: Ammonia/water mixtures at extreme conditions of pressure and temperature

Keywords: planetary ices, high pressure and temperature, melting, phase diagram, diamond anvil cell

Scientific description:

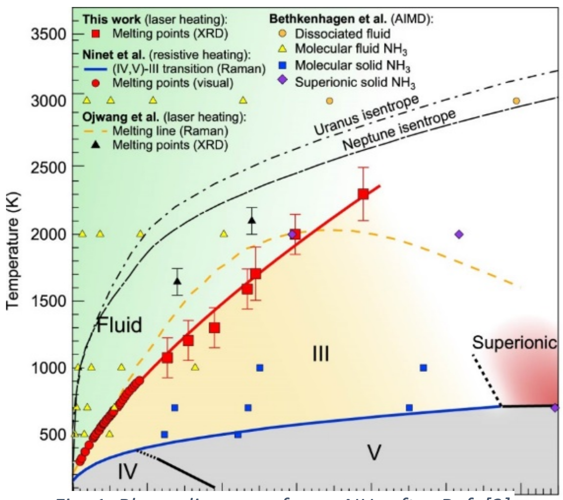

Fig. 1. Phase diagram of pure NH_3 after Ref. [3]

Water and ammonia are two major components of the mantle of the giant icy planets Neptune and Uranus, as well as several moons of Jupiter and Saturn. Constraining the interior structure of these bodies require precise information on water/ammonia mixtures of various compositions and over a large range of pressure (P) and temperature (T) conditions. An important question for planetary models, and in particular for the understanding of their peculiar magnetic fields, relate to the existence and P-T stability domain of a superionic solid phase, characterized by a fast proton conductivity, in the internal ice layer at high P-T conditions. During the last years, after revealing that pressure can induce hydrogen delocalization in superionic, ionic and metallic phases in pure ammonia (Fig. 1) [1-5] and pure water [6], our group engaged in the investigation of the properties ammonia/water mixtures in order to determine whether these exotic phases also exist in the mixed compounds. Our determination of the high P-T phase diagrams of 3 stoichiometric compounds ($xH_2O:yNH_3$) (ammonia monohydrate [7,8], ammonia hemihydrate and ammonia dihydrate) reveal strong similarities and, in particular, the existence of a new proton-disordered phase along the melting line at high P-T.

The present internship will focus on the studies of ammonia/water mixtures with non stoechiometric compositions and will aim to determine their melting curve and phase diagram at high P (20 GPa) and T (800 K). The vibrational and structural properties of the solid phase along the melting line will be determined by Raman and XRD experiments. These experiments will allow to obtain a complete 3D (composition, T, P) binary diagram of water/ices mixtures. The latter is crucial for planetary description since the relative abundance of the two molecules is not well constrained in models of Jovian planets.

[1] *S. Ninet et al., PRL. 108, 165702 (2012)* ; [2] *S. Ninet et al. PRB 89, 174103 (2014),* [3] *J.-A. Queyroux et al., PRB 99, 134107 (2019)* ; [4] *J.-A. Queyroux et al.. PRB, 100, 224104 (2019)* ; [5] *A. Ravasio et al, PRL, 126, 025003 (2021)* ; [6] *J.-A. Queyroux et al, PRL 125, 195501 (2020)* ; [7] *C. Liu, A, et al. Nature Comm., 8, 1065 (2017)* ; [8] *H. Zhang et al. J. Chem Phys. 153, 154503 (2020)*

Techniques/methods in use: Diamond anvil cell, resistive heating, Raman spectroscopy, X-ray diffraction

Applicant skills: Motivation for experimental physics; good background in condensed-matter physics

Internship supervisors : Sandra Ninet, sandra.ninet@sorbonne-universite.fr, 01-44-27-44-22
Frédéric Datchi Frederic.datchi@sorbonne-universite.fr

Internship location: SU, Campus Pierre et Marie Curie, IMPMC, Tower 23 – 3rd floor – 13-23

Possibility for a Doctoral thesis: yes