Measuring the H-He properties under Jupiter interior conditions: challenge, approach, data and implications

S. Brygoo[1], P. Loubeyre[1], M. Millot[2], J.R. Rygg[3], P.M. Celliers[2], J. H. Eggert[2], R. Jeanloz[4] and G.W. Collins[3].

[1] CEA, DAM, DIF, F-91297 Arpajon, France
[2] LLNL, Livermore, CA, USA
[3] LLE, University of Rochester, Rochester, NY, USA
[4] UC Berkeley, Berkeley, CA, USA

Gas giant planets, such as Jupiter, Saturn and most of the exoplanets discovered so far, consist mostly of hydrogen and helium. A major source of influence for their interior models is the possibility of demixing of the warm dense hydrogen/helium mixtures, originally proposed by Salpeter and Stevenson in 1975. Such a H/He phase separation – sometimes pictured as a He rain – would completely change the interior structure and the evolution of these planets. Recently, various ab-initio calculations have predicted the location of the H/He miscibility gap, but these calculations remain challenging, in particular to accurately estimate the temperature and pressure conditions needed to dissociate the hydrogen molecules and the mixing entropy. Using laser-driven shocks in pre-compressed targets allows exploring higher densities and lower temperature than single shock experiments. In particular we can now directly measure the equation of state of H/He mixtures at thermodynamic conditions of deep planetary interiors thanks to a new target design with pre-compressions near 4 GPa. We document first the temperature and optical properties of helium and hydrogen separately than two mixture (11% and 33% He) up to 3 Mbar. A discontinuity of the reflectivity versus shock temperature is observed for the 11% mixture and interpreted as the first experimental signature of H/He phase separation at Jovian planet interior conditions (Nature volume 593, pages517–521 (2021))