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hedla@tecnico.ulisboa.pt

Electrical conductivity and optical properties of hydrogen-helium mixtures in giant planet interiors

F. Soubiran[1,†], G. Salin[1]

[1] *CEA DAM-DIF, 91297 Arpajon, France*

[†] francois.soubiran@cea.fr

The spacecrafts Cassini and Juno have provided exquisite data regarding the internal structure of our gas giant planets Saturn and Jupiter. The gravity data indicated for instance that the envelope of these planets is definitely non uniform and has a variable helium to hydrogen ratio with depth. If the exact composition is yet out of reach because of a large uncertainty on the hydrogen-helium phase diagram, the trend is clear. Both have an enrichment in helium above the megabar level and a helium depletion at lower pressure. For Jupiter a diffuse core may be partially mixed with the helium rich region. For Saturn, the demixing is so pronounced that a nearly pure helium layer is expected in the deepest regions of the planet. But the spacecrafts have also sent back beautiful data regarding the magnetic field. To model the dynamo processes at play it is crucial to have the proper conductivity data of the hydrogen and helium mixtures for different compositions.
Here, we report a large series of density functional theory (DFT) based calculations of the electronic properties of hydrogen and helium mixtures under a large range of thermodynamic conditions relevant for the interior of giant planets. Using linear response theory we determined the conductivity of the mixtures. A simple isobaric isothermal ideal mixing rule, although relatively robust regarding the equation of state of these mixtures, is not satisfactory when applied to the electronic properties. It is thus necessary to carefully consider the mixing effects. We will also discuss how the optical properties can be used to characterize the demixing of hydrogen and helium in shock experiments.