université PARIS-SACLAY
FACULTÉ DES SCIENCES D'ORSAY

cnrs

PROPOSITION DE THESE
Ph.D. offer

Date limite de candidature / application until : 1er mai 2021 / May 1st, 2021

Responsable de la thèse / *PhD supervisor*:

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Nom du Laboratoire / *laboratory name*: Laboratoire de Physique des Gaz et des Plasmas (LPGP)

Code d'identification : UMR 8578 — Organisme / *Institution* : CNRS/U Paris Saclay
Site Internet / *website*: www.lpgp.u-psud.fr
Adresse / *address:* bât. 210, université Paris-Saclay, ORSAY
Lieu de la thèse / *PhD place*: idem

Titre de la thèse / *PhD title*

Emergence de l'auto-organisation dans les plasmas non-équilibre /
On the formation of non-equilibrium in plasmas and the emergence of auto-organization

Résumé / summary

Non-equilibrium physics are ubiquitous for plasmas in the laboratory due to the presence of boundaries to enclose it. The sheath appears in absolutely all kind of plasmas confined either by a solid wall but also by a liquid. It is a universal non-equilibrium phenomenon in the sense that even gravitationally confined plasmas, like a star, also present sheath characteristics on their boundaries. In contact with a surface (either solid or liquid), a plasma sheath forms which is a region where quasi-neutrality of charges is not respected and significant differences in temperatures are observed between different species (more particularly electrons and neutrals). Plasmas are generally considered as the 4th thermodynamic matter state because they show an auto-coherent response to to any kind of external electromagnetic perturbation. Thermodynamics strictly apply to equilibrium conditions. However, a completely new field (spear-headed by the 1977 Nobel prize in Chemistry, Ilya Prigogine) was developed to extend its validity to non-equilibrium conditions, later coined as the field of "non-equilibrium thermodynamics". While the formalism was very successfully applied in various fields such as non-equilibrium oscillating chemical reactions, spots or stripe patterns in fishes and vegetation in semi-arid deserts, its application to low temperature plasmas was under-developed. The formalism has been so far only used to demonstrate that currently used phenomenological equations (meaning: equations which have no a priori fundamental justification) can be used but the power of the formalism to handle non-linearities in plasmas was not used.
One particularly interesting problem is the description in a continuous way of the spatial distribution of species from inside a solid surface to the plasma phase without discontinuities without using any ad hoc assumptions (meaning: tuning parameters without physical justification to adjust a given model). The use of the chemical potential coupled to the Poisson equation will yield for the first time the solution the closest to reality.
First, the student will get used to the non-equilibrium thermodynamics formalism (and more particularly Onsager's relations) and use it to find, analytic solutions for a few pre-determined simple cases. Then, the full solution will be computationally determined and several species implemented. A comparison with classical sheath solutions (kinetic / fluid and PiC) will be performed and conditions for the generation of auto-organization in the bulk of a plasma determined by linear perturbation analysis. Comparison with experiments, whenever available, will be done.
A degree in Physics (or equivalent field) is desired and prior knowledge on plasma physics is a plus but not a requirement. A strong affinity with mathematics and programming as well as English is desired. This PhD

project is within the framework of a joint-cooperation and will be a cotutelle with the "Institut National de la Recherche Scientifique" (Varennes, Quebec/Canada) with one (or more) extended stay(s) planned during the PhD thesis project.

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Début de la thèse / *starting* of the *Ph.D. contract***: *01/10/2021 / October 1st, 2021***

Financement de thèse / *financial support for the PhD***: concours EDOM / '**Doctoral School Matter and Waves', after application and oral defense of the application