Master 2 Internship

Centre de Physique Théorique, UMR 7332 and IRFM CEA

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Title : **Chaotic motion of charged particles in magnetic fields, from single trajectories to collective equilibrium: applications to fusion plasmas.**

General Context:

In the last few years, the impact of low dimensional chaos in the motion of charged particles in ideal plasma configurations has been shown to be able to destroy quasi-invariants in some regions of the phase space. Most notably the existence of an adiabatic constant, namely the magnetic moment μ, which is at the heart of the gyrokinetics reduction appeared to be questionable in these regions, or when it exists, this was shown not to imply the integrability of the dynamics, even in axisymmetric magnetic fields [1–3]. It appeared therefore useful to compute exact equilibrium solutions of the Vlasov equation [4, 5]. Surprisingly these solutions can display a bifurcation from a plasma that is well confined with steep density gradients to one that is less confined. This is reminiscent of the so called L-H transition observed in fusion machine, and is supposedly linked to the presence of a transport barrier [3]. In the present case, the different profiles appear to emerge depending on whether or not unstable points with an associated separatrix exist in the microscopic Hamiltonian dynamics of the particles. During this internship the student will familiarize himself with the problems, and develop new tools both conceptual and numerical. One of the problems being able to analyze the stability of the proposed exact Valsov solution, and analyze the Hamiltonian chaotic behavior of the microscopic trajectories, while measuring the effects on the particle density function. Extracting the fluid properties from the obtained kinetic ones and comparing with magneto-hydrodynamic equilibrium will be another challenge.

This internship could naturally lead to a PhD.

Scientific Environment: This internship work will be part of a long standing collaboration of the CPT with the IRFM of the CEA Cadarache within the French national research federation of magnetic confinement fusion (FR-FCM) and the TOP project from the A*MIDEX initiative. Good knowledge of dynamical systems and classical statistical physics will be a plus, mixing both numerical and analytical work will be expected from the interested candidate.

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[1] B. Cambon, X. Leoncini, M. Vittot, R. Dumont, and X. X. Garbet. Chaotic motion of charged particles in toroidal magnetic configurations. *Chaos*, 24:033101, 2014.

[2] S. Ogawa, B. Cambon, X. Leoncini, M. Vittot, D. Del Castillo-Negrete, G. Dif-Pradalier, and X. Garbet. Full particle orbit effects in regular and stochastic magnetic fields. *Phys. Plasmas*, 23:072506, 2016.

[3] S. Ogawa, X. Leoncini, G. Dif-Pradalier, and X. Garbet. Study on creation and destruction of transport barriers via effective safety factors for energetic particles. *Phys. Plasmas*, 23:122510, 2016.

[4] Shun Ogawa, Xavier Leoncini, Alexei Vasiliev, and Xavier Garbet. Tailoring steep density profile with unstable points. *To be published in Phys. Lett. A*, 2018.

[5] Elias Laribi. Solutions stationnaires de vlasov-maxwell en geometrie cylindrique. Master's thesis, 2018.