Proposta di tesi magistrale

Thesis level: Master (internship at CEA-Cadarache)
Corso di Laurea: Physics
Thesis type: Plasma modeling/numerical (to be carried out by internship at CEA- Cadarache)
Title: Investigation of second-order terms in gyrokinetic models: impact on guiding-center dynamics

Thesis description:

The motion of a charged particle in strong electromagnetic fields is characterized by a fast cyclotron motion around magnetic field lines and slower drifts associated with the motion of the so-called guiding center. Based on the observation that the fast motion is mostly irrelevant for the study of plasma turbulence, reduced kinetic models have been developed in the late 1980s, and numerically investigated in a very active way, starting the early 2000s.

Gyrokinetics is nowadays state-of-the-art for the investigation of plasma turbulence. There is not one gyrokinetic model, but a hierarchy of them, depending on the assumptions made for the reduction. The main element behind a gyrokinetic model is its chosen ordering between the various small parameters characterizing, e.g., the background electric and magnetic field inhomogeneities (resp., ϵ_E and ϵ_B) and the amplitude and the spatial and temporal fluctuations of the perturbing electromagnetic fields (characterized by ϵ , ϵ_ω and $\epsilon_\parallel$). The derivation of a proper gyrokinetic model has to be consistent with the chosen ordering from the particle to the guiding center and from the guiding center to the gyrocenter dynamics. The order at which is reduction is carried out sets the limits of investigation of this model. Currently, all of the numerical codes are first or second order in ϵ_δ.

The overall objective of the internship is to start to assess the importance and impact of second order terms in the gyrokinetic models, depending on the region of interest in the plasma, core versus edge. The proposed strategy is to simplify as much as possible the geometry to isolate the different drifts, and analyze them on simple models to get a clear picture in phase space of the role of the different terms.

A first task is to investigate these effects in a slab geometry with a constant and uniform magnetic field. We will investigate the dynamics of charged particles in the guiding-center approximation. In the expansion in the guiding-center theory, the first order is well known, an ExB drift with FLR effects. However, less is known on the second order terms which change the effective potential felt by the guiding-center dynamics. We will look at the dynamics of these guiding centers in phase space. The importance and influence of second order terms will be assessed in the various regimes of the electric and magnetic fields to determine if and when they need to be taken into account in gyrokinetic codes. This will be tested on various electrostatic potentials, ranging from toy models to more realistic ones.

A second task, which will be addressed depending on the progress of the work, is to extend the study to more complex magnetic geometries, starting first with straight magnetic field lines (and varying amplitudes along these lines) in order to assess the grad-B drifts. Then, by selecting a specific geometry, we will investigate the impact of curvature drifts on the dynamics of the guiding centers. These investigations will be done with the same electrostatic potentials for a comparison with the ExB drift effects.

References:

- R.G. Littlejohn, *Variational principles of guiding center motion*, Journal of Plasma Physics 29, 111 (1983)
- A.J. Brizard and T.S. Hahm, *Foundations of Nonlinear Gyrokinetic Theory*, Reviews in Modern Physics 79, 421 (2007)
- N. Tronko and C. Chandre, *Second-order nonlinear gyrokinetic theory: from the particle to the gyrocenter*, Journal of Plasma Physics 84, 925840301 (2018)

Proposta di tesi magistrale

RFX tutor: P. Innocente
CEA Internal tutors: Guido Ciraolo (CEA, IRFM), guido.ciraolo@cea.fr;
Cristel Chandre (CNRS, laboratoire I2M Aix Marseille University), cristel.chandre@univ-amu.fr;
Academic tutor: L. Giudicotti
Head of research unit: P. Innocente
Submission date: December the 08th, 2020
Status: not assigned