CEA/CADARACHE
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PhD PROPOSAL 2014

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Title : Self-organization of heat and momentum turbulent transport in stars and tokamaks.

Summary :

Although laboratory and space plasmas may be characterized by different magnitudes of critical dimensionless parameters, such as the ratio of the system size over the collisional mean free path (collisionality), the ratio of the Larmor radius over the system size, or the ratio of the kinetic pressure over the magnetic pressure, they also share some common important features. The first one is the tendency to host linear instabilities which are driven by strong departures from thermodynamical equilibrium, and which eventually saturate nonlinearly in a turbulent regime. The result is enhanced transport of heat, matter and momentum, which governs the steady-state equilibrium of these objects. The second one deals with self-organization of turbulence itself, which often manifests through the self-generation of large scale flows and/or fields, and the possible subsequent emergence of transport barriers, i.e. regions of reduced transport.

The objective of the proposed PhD thesis is to study turbulence dynamics in the Sun and in tokamak plasmas, by means of state-of-the-art nonlinear simulations. The nature of turbulence is essentially thermo-convection in both systems. In the Sun, self-organization leads to the existence of the *tachocline*, a thin layer in between the inner radiative zone and the outer convective one, characterized by a strong shear of the azimuthal rotation and which is thought to play a prominent role in the generation and dynamics of the Solar magnetic field. In tokamak plasmas, turbulence is suspected to generate large scale sheared flows, which contribute to the triggering of dynamical transport barriers and the access to improved confinement regimes, which are desirable for ITER.

The work consists in the definition and in the analysis of nonlinear simulations. The runs will be performed on high performance computers (HPC), using massively parallelized codes which have been mainly developed in the hosts labs. The associated theory will be reviewed, and reduced low dimensional models may also be considered. The 3D magneto-hydrodynamical ASH code is run by IRFU/SAp ("Service d'Astrophysique" at the "Institut de Recherche sur les lois Fondamentales de l'Univers") to model the stellar dynamics, while the 5D gyrokinetic GYSELA code is run by IRFM ("Institut de Recherche sur la Fusion par confinement Magnétique") to model electrostatic turbulent transport in tokamaks. Besides, both codes and teams share common views on critical issues regarding the addressed physics: (i) no space and time scale separation between turbulence and equilibrium can be assumed, both needing being treated on an equal footing; (ii) flux-driven global simulations are mandatory in order to allow for self-organization at all scales.

This cross-disciplinary subject follows a previous successful PhD thesis led by the same teams and defended in 2012. It takes benefit from the fruitful interactions between both communities during the "Festival de Théorie", which gathers theoreticians in astrophysics and controlled fusion every odd year during 3 weeks in Aix-en-Provence. The candidate will spend about half time at Saclay and Cadarache.

Skills : Knowledge in plasma physics and/or magnetohydrodynamics. Interest for computational science.