Personal profile: past research experience

During my stay at EPFL, I have had the chance to work on research projects on multiple occasions and continuously over the year: infact, the most relevant research experiences are connected to the three semester projects that I have undertaken (one is in due course) and, most of all, to the summer internship at the Swiss Plasma Center (SPC). In the next lines, I will briefly resume the topic and the content of them:

- Real-time identification of plasma modes in tokamak with SparSpec algorithm:

Fast and reliable techniques to identify the development of modes in the plasma during discharges are essential to guarantee that no unstable (and potentially disruptive) modes are excited in the machine. In this project, I analyzed the approach to the problem via sparse matrices from both a theoretical point of view and by testing the performances of a specific implementation of the method in the SparSpec algorithm. This tool was originally devised for astrophysical purposes, namely in asteroseismology, where it has produced rather good results compared to other techniques. Although the two problems in Astrophysics and Plasma Physics are similar, the latter is much more complex, given two-dimensional space of frequencies (poloidal and toroidal modes), and thus the algorithm needs to be adequately expanded in scope to achieve higher accuracy.

- Statistical study of plasma turbulence in tokamaks:

In this project, I analyzed the phenomenon of plasma turbulence from a statistical point of view and by using the Sridhar and Goldreich model of plasma turbulence, which is connected to the well-known Kolmogorov theory K41. In fact, plasmas are generally characterized by turbulent flow regimes in which fluctuations of the velocity and magnetic field present chaotic changes. In the region of validity of incompressible magnetohydrodynamics (MHD), many studies have hypothesized that plasma turbulence arises from the non-linear interactions between shear Alfven waves that produce an energy cascade from larger scales to smaller scales. This leads to Kolmogorov-like energy spectra that span a broad range of frequencies, as verified through the analysis of turbulence in interstellar medium, solar wind and numerical simulations. In particular, in this project, I investigated scaling behaviours of turbulence in the case of fusion plasmas by analyzing multiple series of data obtained at the TCV (Tokamak à Configuration Variable) facility in Lausanne with the recently installed LTCC3D probes. A first important result is that we can study the properties of magnetic field fluctuations as a non-Markovian stochastic process which exhibits self-similarity at some scales, which points out its fractal nature. My work has been included in a poster presented at the 15th IAEA Technical Meeting on the Energetic Particles in Magnetic Confinement Systems (Princeton, USA) and which is available here:
https://nucleus.iaea.org/sites/fusionportal/Shared%20Documents/EP%2017th/Posters/P-25.pdf

- Quasars spectra recognition with Convolutional Neural Networks:

This semester project is currently in progress and will be completed by January 2018. It is part of the minor in Computational Science and Engineering (CSE) that I am doing, and therefore it has a stronger “computational” side. My task is to use machine learning techniques, in particular convolutional neural neworks (CNN) in the problem of distinguishing between spectra of quasars that exhibit broad-adsorption lines (BAL) and those who do not. The testing database is the BOSS-DR12Q of the Sloan Digital Sky Survey and, if successful, this technique will be of great use in a task that up to now has been mostly performed by visual inspection. All the code that I am writing for this project is in Python.

- Drift-Kinetic model of plasma dynamics, during summer internship at SPC from 24/07/2017 - 08/09/2017:

During this internship at the Plasma Center, I worked on the model of drift-kinetic plasma dynamics developed by R. Jorge, P. Ricci & N.F. Loureiro (available here: https://arxiv.org/abs/1709.01411v1) to describe the dynamics in the region of the so-called scrape-off-layer (SOL) which is situated at the boundaries of the plasma and is much relevant for any progress in magnetic confinement. This region is characterised by turbulent fluctuations of magnitude comparable to the mean quantities and at frequncies lower than the gyrofrequency. Simulations of the SOL dynamics are usually performed via gyrokinetics or fluid models which, however, are computationally expensive or not accurate enough. This alternative approach aims at contructing a moment hyerarchy in the drift-kinetic approximation: the gyroaveraged distribution function is expanded into a Hermite-Laguerre basis such that the coefficients of this expansion will be equal to the moments of the distribution function itself. An equation that involves the moments is then derived and coupled to Poisson's equation. In order to analyse the instabilities in the SOL, the system of equations is linearized in the Fourier space and a generalised eigenvalue problem is set. With this approach, a convergence of the least-damped mode to the kinetic root of the Landau damping is observed. By building on the work already done, my personal contribution was to analitically derive and to implement in the code (written in MATLAB) the perpendicular dynamics in the drift-kinetic approximation, to find efficient ways to solve the generalised eigenvalue problem and to introduce realistic geometries of the magnetic field (namely, the s-alpha curved, concentric model of field lines) in such a way as to account for non-classical trajectories of charged particles in tokamak devices.