Ph-D proposal: Numerical simulation of Magneto-hydrodynamical instabilities in tokamaks

- **Work place**: Inria, Sophia Antipolis Méditerranée
- **Scientific contact**: Herve.Guillard@inria.fr
- **Team presentation**: The Castor team of Inria Sophia-Antipolis has activities in modeling and numerical simulations of fluid models used in plasma physics. One of the main objectives of the team is to contribute to the understanding of controlled nuclear fusion. Castor is an interdisciplinary team composed of applied mathematicians and computer scientists specialized in high performance computing with a strong interaction with plasma physicists involved in the ITER (International Thermonuclear Experimental Reactor) tokamak project currently being build in Cadarache (France).

- **Subject description**:

  **Scientific ans societal context**: In order to fulfill an increasing demand, alternative energy sources have to be developed. Indeed, the current rate of fossil fuel usage and its serious adverse environmental impacts (pollution, greenhouse gas emissions, ...) lead to an energy crisis accompanied by potentially disastrous global climate changes. Controlled fusion power is one of the most promising alternatives to the use of fossil resources, potentially with an unlimited source of fuel. One of the most successful concept for mastering fusion is magnetic confinement where an extremely hot ionized gas called a plasma is confined in a toroidal chamber thanks to a very strong magnetic field. This concept initially pioneered by the Russian physicists Igor Tamm and Andrei Sakharov, is studied in experimental devices called Tokamaks (A russian acronym for toroidal chamber). One of these machines called ITER (for International Thermonuclear Experimental Reactor: https://www.iter.org/fr/org/io) is currently being build in Cadarache (France) thanks to an international agreement involving 35 different countries. The physics of the plasma in a tokamak is extremely complex and its understanding requires a strong interaction between experiments, modeling and large scale numerical simulations. However, thanks to the increasing resources provided by parallel computing, huge progresses have been achieved and it is likely that in the time framework of the construction of ITER, the detailed simulation of some key-points for the operation of the machine will be possible.

  **Ph-D work description**: One of these key-point concerns the mastering of the magneto-hydrodynamical (MHD) instabilities that develop in tokamaks. The numerical simulation of these phenomena is now in position to address the problem of the realistic representation of the complex geometries of today tokamaks. In magnetic confinement modeling, the representation of the magnetic field is usually formulated in terms of vector potential, therefore the resistive terms and the Lorentz force are expressed as third derivatives and the finite element spaces naturally adapted to this situation are described by continuously differentiable (C1) basis functions. The practice shows however that these finite element C1 bases are complex to build and lead to discrete systems difficult to solve. In this work, we propose to study the alternative use of C0 high order bases easier to build for the representation of complex geometries. This implies to design new numerical strategies to represent third order derivatives and to discretize the MHD system of equations. This work will be done in the framework of the development of a numerical platform for tokamak simulation that involve at Inria the CASTOR (Sophia) and TONUS (Nancy-Strasbourg) teams as well as some external partners (Institut fur plasma physics- Garching Germany, Institut de Recherche sur la fusion controlee, CEA cadarache).

- **Skills and profile**: Solid knowledge in applied mathematics and modeling in fluid dynamics or plasma physics. Good programming skills and basic knowledge of parallel computing (MPI - OpenMP) Good command of English as working language. Interest in the interaction with physicists and physical experiments and study experiences out of France are an asset.

- **Contract duration**: 36 month starting from October 1rst 2017

- **Keywords**: Applied mathematics - Numerical Analysis - Scientific computing Plasma Modeling - Nuclear fusion - Tokamaks