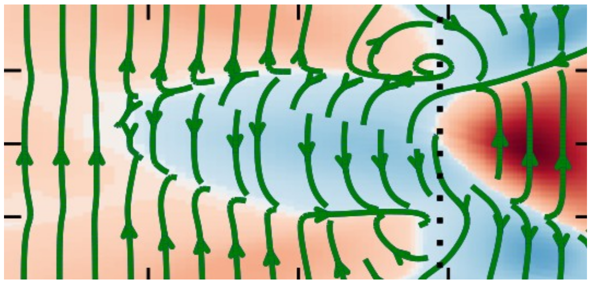
Collisional dynamics of heavy ions in transport barriers of fusion reactors

Background

The steady state temperature gradients sustained in fusion experiments is among the largest in the universe. Magnetic confinement of charged particles make it possible to separate the core of a fusion device, that is ten times hotter the the center of the Sun, from the cryogenically cooled superconductor coils, only a few meters away. Most of this enormous transition takes place in the transport barrier, which is a thin insulating layer in the outer edge of the fusion plasma. In these fascinating formations turbulence is quenched by strong sheared flows, hence the reduced heat and particle transport. The remaining transport processes and the flows themselves are governed by collisional processes, which is the topic of this project.

Problem description



Variations of the poloidal flow speed on a magnetic surface around a transport barrier (color coded), and stream plot of flow patterns inside (vertical) and across (horizontal) the magnetic surfaces.

The plasma in a fusion device is confined by nested magnetic surfaces, so called flux surfaces. The densities and temperatures of the various ion species vary strongly across these magnetic surfaces, but they are approximately constant on them. However in transport barriers heavy ions can develop strong variations on flux surfaces, which has crucial consequences for their transport. The transport of impurities across the transport barrier is one of the most important issues in fusion, because if they can enter the hot core of the plasma and accumulate there, they can damage the fusion performance or even lead to large scale instabilities by diluting the fuel and through radiative heat losses. In this project we focus on how the variation of impurities in flux surfaces affect their dynamics and their collisional transport using advanced numerical simulations.

Thesis description (60 credit project)

The master student will first be introduced to the field of kinetic modeling of magnetized plasmas, with special emphasis on transport in the most successful type of fusion device called the tokamak. After learning about what theoretical complications transport barriers pose in this context and specific methods to model transport in them, the student will be familiarized with a collisional kinetic simulation code developed for transport barriers. A major part of the project will be devoted to derive and implement modifications to the existing model used in the code due to variations of densities on the magnetic surfaces. Finally, the code will be validated to existing analytical theories, in order to then go further to yet uncharted territory of numerical transport modeling in transport barriers.

Literature

- R. D. Hazeltine and J. D. Meiss, *Plasma Confinement*, Courier Dover Publications (2003) [Chapter 4] ISBN: 9780486432427
- M. Landreman et al., 2014, *Radially global δf computation of neoclassical phenomena in a tokamak pedestal*, Plasma Physics and Controlled Fusion **56** 045005.

Supervisor

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