Nonlinear dynamics of zonal flows and geodesic acoustic modes in ITER

Didier GOSSARD[1], Alessandro BIANCALANI[2], Alberto BOTTINO[3], Thomas HAYWARD-SCHNEIDER[3], Philipp LAUBER[3], Alexey MISHCHENKO[4], Martin PUJOL[1], Martin RAMPONT[1], Juvert N. SAMA[5], Laurent VILLARD[6]

[1] École Supérieure d'Ingénieurs Léonard de Vinci, 92916 Paris La Défense, France
[2] Léonard de Vinci Pôle Universitaire, Research Center, 92916 Paris La Défense, France
[3] Max Planck Institute for Plasma Physics, 85748 Garching, Germany
[4] Max Planck Institute for Plasma Physics, 17491 Greifswald, Germany
[5] Institut Jean Lamour UMR 7198, Université de Lorraine-CNRS, Nancy 54011, France
[6] Polytechnique Fédérale de Lausanne, Swiss Plasma Center, CH-1015 Lausanne, Switzerland

contact: didier.gossard ⊕ devinci.fr

The spontaneous formation of turbulence makes the confinement of energy and particles in tokamak plasmas more challenging. Tokamak plasmas are denser and hotter in the core, and lighter and colder at the edge, near the tokamak walls. These spatial gradients of plasma density and temperature excite microinstabilities, which nonlinearly interact forming turbulence. Turbulence enhances the heat and particle transport, decreasing the confinement. Therefore, the importance of understanding the turbulence dynamics comes from the necessity to confine the energy in the core, in order to achieve the conditions for a self-sustained burning plasma in a fusion reactor.

Micro-turbulence generates meso-scale zonal structures, like geodesic acoustic modes (GAM) [2] and zero-frequency zonal flows (ZFZF) [1]. Energetic particles (EP), present due to external heating mechanisms or fusion reactions, can drive GAMs due to inverse Landau damping, taking the name of EP-driven GAMs (EGAM).

In this paper, we investigate the dynamics of zonal flows in the absence and in the presence of EPs with the gyrokinetic particle-in-cell code ORB5 [3]. The ITER pre-fusion-power-operation plasma scenario [4] is considered for these numerical simulations. First, the linear dynamics of zonal flows has been analysed for off-axis bump-on-tail EP profile. The emergence of a threshold of instability has been demonstrated and the appearance of EGAMs has been predicted. After, the nonlinear interaction of EPs and EGAMs has been investigated. The EGAM up-chirping has been highlighted and the EP redistribution in phase space has been observed.

References

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