Transport hysteresis and zonal flow stimulation in magnetized plasmas

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A study of zonal flows generated by trapped-electron mode (TEM) and trapped-ion mode (TIM) micro turbulence is presented as a function of the temperature ratio T_e/T_i. For this purpose the gyrokinetic code TERESA (Trapped Element REduction in Semi lagrangian Approach) considering only trapped particles is used [1, 2, 3, 4, 5, 6]. The model enables the study of a full f problem for ion and electron trapped particles at low numerical cost.

A hysteresis in the relationship between zonal flows and electron heating is observed. As the electron temperature increases, a first transition occurs, at a given electron/ion temperature ratio, above which zonal flows are much weaker than before the transition, leading to a poorly confined plasma [6, 7]. Beyond this transition, even if the electron temperature is lowered to a moderate value, the plasma fails to recover a dynamic state with strong zonal flows. Then, as the electron temperature decreases further, a new transition appears, at a temperature lower than the first transition, below which the zonal flows are stronger than they were initially [8]. The confinement of the plasma and the heat flux are thus found to be sensitive to the history of the magnetized plasma. These transitions are associated with large exchanges of energy between the modes corresponding to instabilities ($m > 0$) and zonal flows ($m = 0$). We also observe that up to the first transition it is possible to use a control method to stimulate the appearance of zonal flows and therefore the confinement of the plasma. Beyond that transition, this control method is no longer effective.

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