An analytical model reveals the origin of the effect of magnetic geometry on Trapped Electron Mode instability in tokamak plasmas

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Plasma confinement is one of the key issues for tokamaks operation. It is related to heat and particles transport, which is driven by turbulent dynamics in fusion regimes. The shape of the magnetic configuration has an impact on turbulent transport. In particular, it has been shown experimentally for the tokamaks TCV [1] and DIII-D [2] that a special magnetic geometry, where the cross-section of the plasma torus exhibits a reversed “D” shape (“negative triangularity”), reduces the turbulent transport, hence improving confinement. A key instability mechanism for explaining this effect is the so called “trapped electron mode” (TEM) [1] instability, associated with the presence, in an inhomogeneous magnetized plasma, of electrons whose parallel energy is not sufficient for their trajectories to explore the whole magnetic field line, leaving them “trapped” in a magnetic well.

In this framework, in order to get a physical understanding of the reduction of TEM turbulence in negative triangularity plasmas, a reduced analytical model for finding the linear growth rates of the instability as a function of plasma shaping has been recently developed [3]. The model is based on a class of local magnetic equilibria [4] and assumes a kinetic response of trapped electrons to the perturbed electro-static potential, while an adiabatic response is used for ions and passing electrons. It allows an easy computation of several key quantities for TEM to clearly identify their impact on the stability of the modes.

TEM growth rates are found to be reduced in negative triangularity plasmas only when the electrostatic field is assumed ballooned in the poloidal direction, being stronger in the low magnetic field region (outer region of the poloidal cross-section). Such an effect is due to the fact that this region is more unstable to the interchange instability than the inner part of the plasma. When including an ions kinetic response to the perturbation, the dependence of the growth rate on the ballooning of the electro-static field is even stronger, confirming its key role. The predictions of this analytical model are in qualitative agreement with previous linear gyrokinetic simulations [5]. A quantitative comparison with dedicated gyrokinetic simulations will also be presented.

References

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