Helically trapped electron mode in the W7-X stellarator

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The first global gyrokinetic simulations of the helically-trapped electron mode (HTEM) in the Wendelstein 7-X stellarator are presented. The capability of simulating 3D equilibrium has been developed in the GTC code [1] and has allowed us to simulate, for example, microturbulence [2], neoclassical transport [3] and collisonless zonal flow damping [4] in the LHD and W7-X stellarators.

GTC simulations with kinetic electrons, using a 3D equilibrium provided by VMEC, exhibit an unconventional trapped electron mode in W7-X. The eigenmode extends along the field lines and shows a strong variation in the toroidal direction as it was the case in ion temperature gradient (ITG) simulations [2]. However, HTEM is located in the inner side of the torus where the magnetic field strength is weak and the curvature becomes unfavorable in the so-called 'straight' sections of the W7-X (see Figure 1). The HTEM is excited by helically-trapped electrons due to the W7-X magnetic configuration when a density gradient is set. In contrast to tokamaks, HTEM propagates poloidally in the ion diamagnetic direction.

Further nonlinear simulations show that turbulence spreads along all directions after saturation. Although zonal flows are the main saturation mechanism for ITG [2], zonal flows appear to be a subdominant in HTEM simulations. An inverse cascade in toroidal harmonics is observed during saturation which is enhanced by the excitation of low-n harmonics. HTEM can cause significant particle transport comparable to heat transport in ITG simulations with a similar normalized temperature gradient. Nevertheless, preliminary simulations with a similar normalized gradient in both density and temperature exhibit a low transport level consistent with the 'stability valley' found in W7-X [5].

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References

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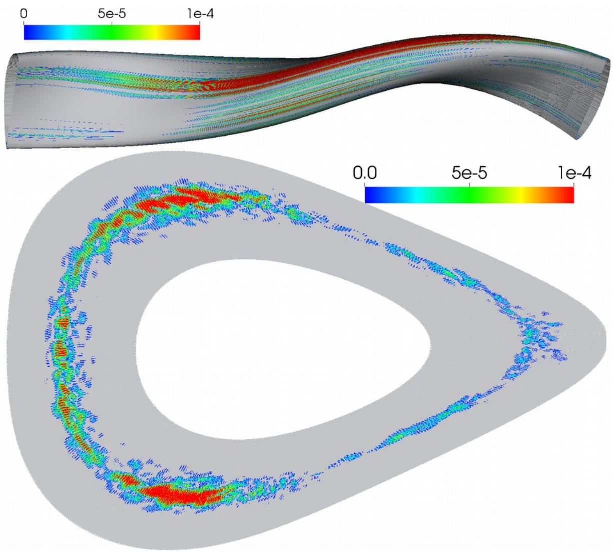

Figure 1: Electrostatic potential in a flux surface (upper panel) and in a poloidal cross section in the “straight” section (lower panel) in W7-X stellarator.