Helimak Fluctuation Analysis comparing Fluid Simulations and Data

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We compare fluctuation data from the Helimak, including electrostatic and magnetic probe data, with theory and three-dimensional nonlinear numerical simulations. The magnetic data is a new feature of the study compared with the work of Perez *et al* Physics of Plasmas, **13**(3),032101(2006) where electrostatic drift modes were identified. To study the magnetic fluctuations, new magnetic probes were designed and used in 2006 and 2007 experiments. The data is from Argon at $n_e = 10^{11}$/cc and $T_e = 10$ eV with $B = 600$G. The toroidal curvature gives a large effective gravity that is pointing in the stable direction on the inside of peaked density profile and in the unstable direction outside the peak. The corresponding change in the fluctuation level and character is clear in the data and simulations. The Helimak is effectively the slab model historically used by theorists in tokamaks. The plasma has the effective $q(r) = q_o(r_0/r)^2$ so that the shear parameter is $s = -2$ characteristic of Advanced RS Modes in tokamaks in the reversed magnetic shear region. The flow shear is externally controlled by end plate biasing. The parallel wavenumber varies over a wide range from resistive MHD to drift wave regimes. With high flow shear turbulence we see a generation of magnetic fluctuations in qualitative agreement with the resistive-viscous fluid simulations. A slab geometry is used, with no slip boundary conditions in the inner $r_1 = 60$ cm and outer wall $r_2 = 160$ cm are used, with periodic boundary conditions in the other two directions. The nonlinear code is a pseudospectral-collocation code with Chebyshev polynomials in radius to allow arbitrary profiles. Time is discretized with a third-order Runge-Kutta–Crank-Nicolson scheme. Important features of the code include three spatial dimensions, the presence of walls, and the inclusion of resistivity and viscosity. For the experimental conditions the code shows Alven-like shear flow driven instabilies with magnetic turbulence. The full spectrum of stable and unstable eigenvalues and eigenfunctions are obtained.

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