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First Simulations of Turbulent Transport in the Field-Reversed Configuration

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Experimental progress by TAE Technologies has led to successful suppression of MHD instabilities in field-reversed configuration (FRC) plasmas using C-2U and C-2W devices. Resultant particle and energy confinement times are on the order of several milliseconds, governed by micro-turbulence driven transport processes. Understanding these mechanisms is essential towards improved confinement and a viable FRC fusion reactor.

Experimental measurements of low frequency density fluctuations in C-2 have shown that fluctuations of the FRC core and SOL exhibit distinct qualities. In the SOL, fluctuations are highest in amplitude at ion-scale lengths and exponentially decrease towards electron-scale lengths. In the core, fluctuations are overall lower in amplitude with a dip in the ion-scale lengths and a slight peak in electron-scale lengths. Using the Gyrokinetic Toroidal Code (GTC), local linear simulations of driftwave instabilities have found qualitatively similar trends. The SOL is linearly unstable for a wide range of length scales and pressure gradients. On the other hand, the core is shown to be robustly stable due to the stabilizing FRC traits of short field-line connection lengths, radially increasing magnetic field strength, and the large finite Larmor radius (FLR) of ions.

To address micro-turbulence in a global FRC magnetic geometry that spans the separatrix, A New Code (ANC), a particle-in-cell code closely related to GTC, has been developed. Nonlocal cross-separatrix simulations show fluctuations spreading from the SOL to the core with fluctuations in the core saturating at levels an order of magnitude lower than in the SOL, consistent with experimental measurements. Turbulence simulations, domain limited to the SOL, show saturation without zonal flow is achieved at levels around e_phi/T_e ~ O(10^-2), and an inverse spectral cascade is observed.

Recent calculations have been extended to more realistically simulate cross-separatrix turbulence. Initial global turbulence simulations show the evolution of the fluctuation spectrum to be comparable to the experimental measurements. In this paper, global turbulence simulations will be compared with experimental results from C-2 and C-2U. The effects of sheared flows, zonal flow, and kinetic electrons and ions on turbulent transport physics will also be reported.

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