Electron Temperature Gradient Turbulence: Validation in the Columbia Linear Machine Experiments

X. Fu, W. Horton
Univerisity of Texas at Austin
A. K. Sen
Columbia University, New York
Y. Xiao, Z. Lin
University of California, Irvine

The electron temperature gradient (ETG) mode, which is a dominant universal mechanism for turbulent electron thermal transport in plasmas, is produced and verified in steady state, collisionless hydrogen experiments conducted in the Columbia Linear Machine[1]. Using a variable cathode-to-anode voltage on the inner half of the plasma radius, electron temperature profiles with steep radial gradients are readily produced. The ion temperature is low with a flat radial profile. The plasma has a high frequency spectrum of ETG driftwaves that responses with changes in the temperature gradient as given by theory and simulations. We report modes at $\sim 0.3 - 0.5$ MHz, with azimuthal wave numbers $m \sim 14 - 16$ and parallel wave number $k_{\|} \sim 0.003$ cm^{-1}. We study these results using (1) gyro-fluid simulation code the IFS-DTRANS code and (2) the gyro-kinetic simulation code GTC[2]. The results show that in the linear phase, the dispersion relation is consistent with kinetic theory for a slab ETG model and the radial structure of the fluctuation agrees with the experiment. We report on the the saturation of ETG mechanism including ponderomotive force driving of the low m-modes by beats of the high m-modes. We also examine nonlinear Landau damping of the beat waves. The fluctuation amplitudes are consistent with the theoretical models and comparable that from turbulent $\mathbf{E} \times \mathbf{B}$ mixing formulas. The low frequency drift-ion acoustic waves [3] are stable and absorb energy from the high frequency ETG modes similar to the nonlinear spectrum given for the tokamak plasma by Horton et al. [4]

References

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