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

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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 respond to changes in the temperature gradient as given by theory and simulations. We report ETG modes at $\sim 0.3 - 0.5$ MHz, with azimuthal wave numbers $m \sim 14 - 16$ and parallel wave number $k_\parallel \sim 0.003$ 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 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