Instabilities and transport in ExB plasma discharges

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We describe an hierarchy of nonlinear fluid models describing fluctuations and instabilities in plasma discharges supported by ExB electron current. For typical parameters, partially magnetized plasma with magnetized electrons and non-magnetized ions is considered. The nonlinear equations for electrons are reduced using the low-frequency approximation $\omega << \omega_{ce}$ while the ion equations include full dynamics. The resulting equations describe several fundamental modes of partially magnetized plasma: ion sound mode, lower-hybrid mode and anti-drift mode due to plasma density gradient. Density and magnetic field gradients and the electron current result in complex coupling of various modes destabilized by the interplay of ExB drift, ion beam velocity, density and magnetic field gradients, collisions and ionization. The nonlinear simulations have been performed to investigate the nonlinear saturation of the instabilities and resulting nonlinear transport. The simulations demonstrate highly intermittent electron current with magnitudes generally consistent with typical experimental parameters. It is shown that while the most unstable are small scale modes, the dominant contribution to the anomalous transport is provided by the large scale modes. The nonlinear energy transfer to large scale modes is demonstrated in nonlinear simulations. Role of parallel electron dynamics and sheath boundary conditions is studied. It is shown that the boundary sheath can screen bulk plasmas so that the effective parallel wave-vector turns out to be much smaller than the naïve geometric estimate $k_{\parallel} \approx 1/L$, where L is the plasma length along the magnetic field. The role of electron-cyclotron instabilities detected in PIC simulations is also discussed.