Nonlinear Dynamics of Fluctuations and Sheared Flows Under Biasing in a Magnetized Laboratory Plasma

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Laboratory experiments utilizing two sets of biased electrodes to affect the plasma potential profile and velocity (flow) shear in a linear device are described. The experiments were conducted in the HelCat (Helicon-Cathode) device - a 4 m long, 50 cm diameter experiment with dual plasma sources (RF helicon and thermionic cathode). Typical helicon plasma parameters are n ~ 510 ×10^18 m^-3, Te ~ 5 eV, and B 0.22 Tesla. A grid electrode was placed at the source end of the experiment (~ 10 cm in front of the helicon antenna) and biased with respect to the vacuum chamber wall, while a set of concentric ring electrodes terminated the plasma column at the far end and was biased in various ways. With increasing ring bias relative to the wall, it is found that both axial and azimuthal flow shear change by modest amounts in magnitude, but move inward to the plasma core from the wall. As the ring bias is increased from zero, drift waves decrease in amplitude and are eventually fully suppressed, at which point a second mode - tentatively identified as a rotation-driven interchange mode - is destabilized. Fluctuations show increasingly chaotic and intermittent behaviour as bias increases, up to V ~ 10kTe/e. The Reynolds Stress, vr x v = E x Er/B0 , decreases monotonically with bias until the second mode appears, then increases again. At high bias, V ~ 10kTe/e, the chaos disappears, as indicated by a rapid drop in correlation dimension, and there is a sharp drop in radial fluctuation-driven transport, leading to a transport barrier-like condition. In contrast, increasing positive bias on the grid electrode is found to cause large changes in axial flow, and to affect fluctuation dynamics in more complicated ways. Grid bias > 3kTe/e appears to affect the source coupling (these results may help to elucidate helicon physics, e.g. formation of an electron beam). Additionally, the nonlinear dynamics of the fluctuations are found to have a complicated, nonlinear dependence on magnetic field, B0. Experimental results, linear stability analysis of the fluctuations, and a three fluid model (ions, thermal electrons, fast electrons) of grid-generated axial flow are presented. Initial work on nonlinear modelling will also be discussed.

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