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Experimental Observation of mesoscale turbulence and Role of $V_{E\times B}$ Shear flow in H-mode DIII-D Plasmas

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We report on the enhancement of streamer-like, mesoscale electron density fluctuations in high collisionality H-mode plasmas with collapsed mean $E_r \times B$ shear flow on the DIII-D tokamak. These findings may also serve as a candidate explanation for the unfavorable confinement scaling of collisionality in tokamaks ($B\tau_E \sim \nu_e^{*-0.5}$) [1].

In this study, substantial changes in the mean $E_r \times B$ flow and its shearing rate, which are obtained from radial force balance using measurements from the CER diagnostic, have been achieved in this dimensionless collisionality scan experiment, i.e., by varying the collisionality and keeping the plasma density and some important dimensionless parameters fixed (e.g., ρ_*, β_N, q, T_e/T_i, etc.). In high collisionality shots with collapsed mean $E_r \times B$ shear flow, density fluctuations with a long radial correlation length are observed between ELMs in the mid-radius region ($0.4 < \rho < 0.8$) by the Doppler backscattering system. In low collisionality discharges with the strong mean $E_r \times B$ shear flow, such fluctuations are strongly suppressed. The radial correlation length of this density fluctuation is as large as $\Delta r/a \approx 0.15$ ($k_r\rho_s \approx 0.2-0.4$), while the poloidal wavenumber is in the range of $4-9\,\mathrm{cm}^{-1}$ ($k_\theta\rho_s \approx 1.5-4$), indicating radially elongated, mesoscale-type structures. The density fluctuations also exhibit intermittent statistical features, such as high skewness ($S=1$) and kurtosis ($K=3$) as well as a relatively large Hurst exponent ($H \approx 0.7$). The inferred poloidal phase velocity of this mode is about $20-30\,\mathrm{km/s}$ in the electron diamagnetic drift direction in the plasma frame. The radial correlation length of the intermittent mesoscale turbulence is also found to be inversely correlated with $E_r \times B$ flow shearing rate. These findings indicate the potential role of the $E_r \times B$ shear flow in regulating the mesoscale turbulence in high-β H-mode plasmas.

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References

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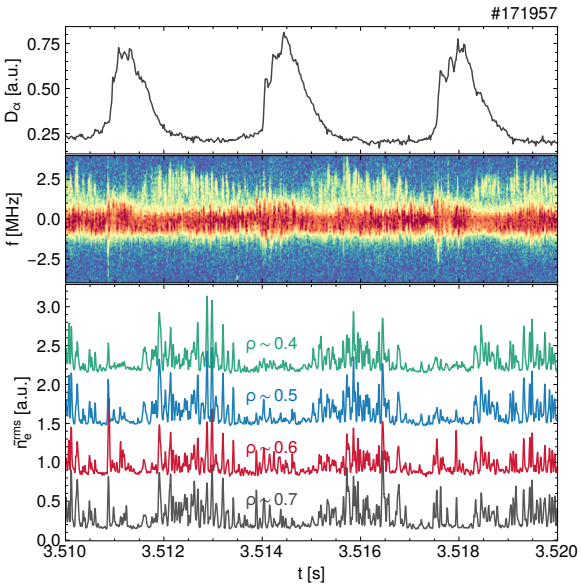

Figure 1. (Top panel) Time history of D_α emission intensity. (Central panel) Spectrogram of density fluctuations at $\rho \approx 0.5$ measured by the Doppler backscattering diagnostics. (Bottom panel) The root-mean-square level of the electron turbulence at different radial locations (with offsets) measured by the Doppler backscattering system.