Observation and Characterization of Radially-Sheared Zonal Flows in DIII-D*

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Zonal flows, predicted to be crucial to the saturation and self-regulation of turbulence and turbulent transport in magnetically-confined plasmas, have been observed and characterized in the outer region of DIII-D plasmas. These flows exhibit temperature scaling characteristics and spatial features predicted for geodesic acoustic modes (GAMs), a class of higher-frequency zonal flows seen in nonlinear simulations of plasma turbulence. The zonal flows (GAMs) have been observed in the turbulence flow-field in the radial region $0.85 \le \mathrm{r/a} \le 1.0$ [M. Jakubowski *et al.*. Phys. Rev. Lett. **89**, 265003 (2002)] via application of time-delay-estimation techniques to two-dimensional measurements of density fluctuations, obtained with Beam Emission Spectroscopy (BES). The density fluctuations are sampled with one cm radial and poloidal resolution over a 5x6 cm grid near the outer midplane at a sampling rate of 1 MHz. Spatial and temporal analysis of the resulting flow-field demonstrates the existence of a coherent oscillation (approximately 15 kHz) in the poloidal flow of density fluctuations that has a long poloidal wavelength, possibly $m=0$, narrow radial extent ($k_r\rho_I < 0.2$), and whose frequency varies monotonically with the local temperature. The approximate effective shearing rate, $\mathrm{dv}_\theta/\mathrm{dr}$, of the flow is of the same order of magnitude as the measured nonlinear decorrelation rate of the turbulence, suggesting that the zonal flow shear is of sufficient amplitude to affect the ambient turbulence. Furthermore, the density fluctuation amplitude is indeed modulated at the frequency of the observed flow oscillation, indicating feedback of the flow oscillation on the turbulence itself. Some phase coherence is observed between the higher wavenumber density fluctuations and the low frequency poloidal flow oscillation, suggesting a nonlinear interaction between turbulence and flow. These characteristics are very similar to predicted features of zonal flows, specifically identified as geodesic acoustic modes, observed in 3-D Braginskii simulations of core/edge turbulence.

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