Flow shear, turbulence and zonal flows in MAST

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Ion-scale $(k_z\rho_i < 1)$ density fluctuations in the outer core region of MAST plasmas have been measured using an imaging BES diagnostic. Correlation analysis is used to extract the characteristics of this turbulence, including radial and poloidal correlation lengths $\ell_{x,z}$, wavenumbers $k_{x,z}$, correlation times τ_c [1], and poloidal velocity fluctuations $\widetilde{U}_z$.

The average 'tilt' of the turbulent eddies in the radial-poloidal plane can be quantified in terms of the parameter $\Theta = \tan^{-1}(k_x/k_z)$, determined from 2D correlation functions $C(\Delta x, \Delta z, \Delta t = 0)$. The tilt is a direct observation of the effect of flow shear, which is theoretically predicted to be given by: $\tan\Theta \sim \gamma_E\tau_c$, where $\gamma_E = U_z'$ is the shearing rate [2]. Results from a database of over 50 discharges, are consistent with this prediction, showing a clear correlation between the tilt Θ and the shearing rate. Little dependence of the radial correlation length ℓ_x or τ_c on the shearing rate is observed, whilst the poloidal wavenumber k_z decreases with increasing shear.

An inverse correlation is also observed between Θ and the gyro-Bohm normalized turbulent heat flux $Q_{i,BES}/Q_{gB}$, which can be estimated from the turbulence characteristics alone, and is shown to be consistent with that from power balance. The dominant effect on the reduced heat flux is due to a reduction in the turbulence amplitude, possibly a result of the increase in the radial wavenumber k_x as has been predicted theoretically [3].

Poloidal velocity fluctuations $\widetilde{U}_z$, calculated using cross-correlation time delay techniques, exhibit significant power at low frequencies ($f < 3$kHz) and spatial coherency with a radial correlation length of between $5 - 10$cm. This result is consistent with DBS measurements on MAST and similar to features observed in other experiments [4], which have been attributed to zonal flows. This data has been incorporated into our database of turbulent and equilibrium parameters, thereby allowing the dependence of the power and coherency of the $\widetilde{U}_z$ data on other parameters, e.g. collisionality or shear, to be determined.

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