New Results on the Theory Anomalous Transport Reduction by shearing: Mean shear and zonal shears

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Abstract

The reduction of turbulent transport by shearing is critical for the transition to H-mode and for the formation of internal transport barrier. While recent experiments indicate rather strong suppression of heat and particle transport $\propto \Omega^{-\alpha}$ $(1.6 < \alpha < 4.8)$ [1], the understanding and theoretical prediction of this scaling is still lacking.

We report the reduction in the transport of particle and heat by a strong mean shear flow in the interchange and ion-temperature gradient turbulence models. Compared to the passive scalar transport [2], a stronger reduction in the transport (down to $\Omega^{-3}\ln\Omega$) results from a severe reduction in the amplitude of turbulent velocity in both models. However, the cross-phase is only modestly reduced, similar to the scalar field case [2], and contrary to recent claims in the literature [3]. These results highlight the importance of the property of the flow in determining the overall transport level.

We also assess the efficiency of *random shearing* by *zonal flows* in transport reduction in a scalar field model. In the strong shear limit, the flux is found to have a similar scaling with the RMS shear Ω_{rms} as $\propto \Omega_{rms}^{-1}$, compared to the case of a coherent shearing. A random zonal flow with a finite correlation time τ_{ZF} renders decorrelation of two nearby fluid elements less efficient, with its time $\tau_D = (\tau_\eta/\tau_{ZF}\Omega_{rms}^2)^{1/2}$ (τ_η is turbulent scattering (diffusion) time), leading to larger amplitude with a slightly different scaling ($\propto \tau_D/\Omega_{rms}$). If $\tau_{ZF} \gg \tau_D$, results recover those for steady linear shear flow. Thus, the effectiveness of zonal shear decorrelation depends on *both* the strength of the shear *and* its auto-correlation time.

[1] J. Boedo, *et al*, Phys. Rev. Lett. **84**, 2630 (2000).

[2] E. Kim and P.H. Diamond, Phys. Rev. Lett. **91**, 075001 (2003).

[3] P.W. Terry, *et al*, Phys. Rev. Lett. **87**, 185001 (2001).