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How Turbulence Spreading Decouples the Flux from the Local Gradient: a Nonlinear Gyrokinetic Simulation Study

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Understanding and prediction of turbulent transport are crucial to achieving improved confinement states in advanced magnetic fusion reactors. However, conventional transport models based on the local saturation paradigm fail to explain many experimental phenomena, e.g. the broken gyro-Bohm scaling, the stiffness of ion temperature profile etc. Nonlinear turbulence spreading in inhomogeneous plasma turbulence can explain the discrepancies [1] by decoupling local turbulence intensity, and thus turbulent flux, from the local gradient. In this contribution, we report on a gyrokinetic simulation study of turbulence spreading, especially focusing on its effects on ion heat transport under conditions of variable magnetic shear and external toroidal rotation shear. These are known to be critical to controlling ion heat transport in experiments [2]. Our key findings from the simulations are two: 1) nonlinear turbulence spreading is enhanced at low magnetic shear, and 2) ion heat transport is more effectively reduced by the suppression of turbulence spreading due to external rotation shear in low magnetic shear region. Sheared toroidal rotation is more effective on the decorrelation of turbulence in the low magnetic shear region.
Our result is consistent with the findings of recent stiffness control experiments [2], where the combination of low magnetic shear and external rotation shear was shown to be effective in controlling T_i-profile stiffness. As turbulence spreading is very likely an important contributor to the ion heat transport dynamics in experiments, our novel findings suggest a new interpretation of de-stiffening.

[1] T.S. Hahm, et al, Plasma Phys. Control. Fusion 46, A323 (2004)

[2] P. Mantica, et al, Phys. Rev. Lett. 107, 135005 (2011)

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