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Gyrokinetic theory of turbulent acceleration of parallel rotation and momentum conservation

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Intrinsic flow drive by both electrostatic turbulence and electromagnetic turbulence are investigated. A new mechanism for turbulent acceleration of parallel rotation in electrostatic ion temperature gradient (ITG) is discovered from electrostatic gyrokinetic theory [1]. The turbulent acceleration acts as a local source/sink, which cannot be written as a divergence of the parallel Reynolds stress. It has different physics from the residual stress, which enters the rotation equation via its divergence. A new candidate mechanism for the origin of spontaneous rotation is thus revealed. Both the parallel residual stress and parallel turbulent acceleration driven by electrostatic collisionless trapped electron mode (CTEM) turbulence are also calculated. Via comparison between the cases for ITG and CTEM, a possible connection of these theoretical results to experimental observations of electron cyclotron heating effects on toroidal rotation is discussed [2].

Recent experimental results show that the fluid Reynolds stress cannot explain the rotation profile [3], and kinetic stress can drive parallel rotation [4]. Therefore, we extended our previous work to electromagnetic turbulence. The quasilinear intrinsic parallel flow drive including parallel residual stress, kinetic stress, cross Maxwell stress and parallel turbulent acceleration by electromagnetic ITG turbulence is calculated analytically using electromagnetic gyrokinetic theory. Both the kinetic stress and cross Maxwell stress also enter the mean parallel flow velocity equation via their divergence, as for the usual residual stress. The turbulent acceleration driven by ion pressure gradient along the total magnetic field (including equilibrium magnetic field and fluctuating radial magnetic field) cannot be written as a divergence of stress, and so should be treated as a local source/sink. The possible implications of our results for experimental observations are discussed [5]. To claify that turbulent acceleration does not contradict the momentum conservation, we also present the relationship between turbulent acceleration and momentum conservation in electromagnetic turbulence [6]. Our ongoing work focus on toroidal roation by taking toroidal effects into account [7].

References

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