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Multi-Scale ITG/TEM/ETG Turbulence Simulations with Real Mass Ratio and Beta Value

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Understanding electron heat transport is one of the critical issues in ITER. Although electron temperature gradient (ETG) driven turbulence has been regarded as a candidate of electron heat transport, recent multi-scale plasma turbulence simulations have reported that ion-scale instabilities such as ion temperature gradient modes (ITGs) and trapped electron modes (TEMs) dominate heat transport not only of ions but also of electrons. However, their simulations are limited to the reduced ion-to-electron mass ratios and electrostatic (beta=0) approximation, the following points are not yet clarified: (i) Are ETGs negligible even with the real mass ratio, where ion and electron scales are separated by a factor of the square root of the ion-to-electron mass ratio (˜ 43)? (ii) Does ion-scale turbulence dominate heat transport even with the real beta value, where electromagnetic (finite-beta) effects stabilize ITGs but not ETGs? To resolve these issues, we have carried out multi-scale plasma turbulence simulations employing the real mass ratio and beta value, which is first realized by developing massively parallel finite-difference/spectral methods for the electromagnetic gyrokinetic simulation code GKV.

Our study reveals real-mass-ratio and real-beta effects on multi-scale turbulence: (i) Ion-scale turbulence eliminates electron-scale turbulence and dominates electron heat transport even when employing the real mass ratio and beta value. (ii) When growth rates of ITGs are reduced by the finite-beta effects, full-spectrum analyses of multi-scale turbulence are essentially required. The results suggest that the simulations resolving only ion scales give good estimates only if ion-scale modes are highly unstable. On the other hand, in high-beta regimes where ion-scale modes are stabilized, proper treatments of the contributions of electron scales are important for evaluating transport levels and modeling turbulent transport.

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