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Gyrokinetic analysis of the effects of electron-scale turbulence on ion-scale micro-instabilities

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Most previous studies on plasma turbulence have assumed scale separation between electron-scale (~ electron gyro-radius) and ion-scale turbulence (~ ion gyro-radius). However, multi-scale turbulence studies by using the latest supercomputers indicated existence of cross-scale interactions and its significant impact on turbulent transport, and are necessary for explaining experimental transport levels. Our recent work revealed a part of the cross-scale interactions: suppression of electron temperature gradient modes (ETG) by flow shears in ion temperature gradient mode (ITG) turbulence, and enhancement of ion-scale transport due to damping of the zonal modes by electron-scale turbulence. Since effects of electron-scale turbulence on ion-scale transport have not yet been fully revealed, it is important to explore the physical process in detail and to extend the analysis to other micro-instabilities. Here, we report two analyses: (i) detailed investigation of the damping effects of ETG turbulence on zonal flows created by the ITG turbulence, and (ii) effects of the ETG turbulence on linear growth of the micro-tearing mode (MTM).
First, we have analyzed the ITG/ETG turbulence simulation by using the gyrokinetic entropy transfer analysis. It is revealed that the zonal modes are mainly driven by the ion-scale modes, where relatively higher-wave-number modes are driven by the coupling with the twisted mode caused by kinetic electrons. Electron-scale turbulence effectively damps these higher-wave-number zonal modes. Second, we have investigated the effect of ETG turbulence on linear MTM growth. It is observed that the growth of MTM can be suppressed as ETG-driven turbulent fluctuations increase, which suggests that the ETG turbulence may interrupt the linear MTM growth. Our analyses shed a light on the effects of electron-scale turbulence on ion-scale micro-instabilities: (i) ETG turbulence damps relatively higher- wave-number zonal flows created by ITG turbulence with twisted modes, and (ii) ETG turbulence can distort the resonant mode structure of MTM and interrupt its linear growth. In both cases, kinetic electrons play important roles such as creation of the twisted mode and of the current sheet. This emphasizes the significance of intermediate-scale structures for the cross-scale interactions.

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