Session: Plenary 1

A Model for the Saturation of Multi-scale Turbulence*

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Two important regimes, observed in non-linear gyrokinetic turbulence simulations, are not well modeled by the TGLF quasilinear model. The first is the Dimits shift regime characterized by a non-linear upshift in the effective critical ion temperature gradient above the linear threshold. The second is the electron temperature gradient (ETG) streamer regime characterized by high electron scale turbulence when the ion scale turbulence is weak or stable. The Dimits shift impacts the predicted temperature profile in the deep core. The streamer regime is important when the temperature gradient of the electrons exceed that of the ions. A new model of the saturated turbulence spectrum will be shown to be able to match the turbulence driven transport fluxes in both of these regimes when applied to the TGLF quasilinear model. Analysis of the spectrum of the saturated electric potential fluctuations from multi-scale (both ion end electron scales) gyrokinetic turbulence simulations in tokamak geometry [1] reveals that fluctuating zonal (axisymmetric) ExB flows couple the ion and electron scales. The zonal flows are driven by the ion scale instabilities but strongly regulate the amplitude of the electron scale turbulence. When the linear growthrate of the ETG modes exceeds the zonal flow mixing rate due to advection of the ETG modes, the electron scale turbulence can grow to large amplitude (streamer regime). The standard paradigm that the turbulence is saturated when the zonal flow shearing rate competes with linear growth cannot explain the saturation of the electron scale turbulence. Instead, it is the mixing rate of the zonal ExB velocity spectrum that competes with linear growth at both electron and ion scales. A model of the zonal flow mixing is shown to be able to capture the suppression of electron-scale turbulence by ion-scale turbulence and the threshold for the increase in electron scale turbulence when the ion-scale turbulence is reduced. The Dimits shift results from the impact of the zonal flow mixing on the ion scale turbulence amplitude.

[1] N. Howard and C. Holland et al., Nuclear Fusion 56 (2015) 014004.

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