Improved ITER performance modeling via zonal-flow stabilization

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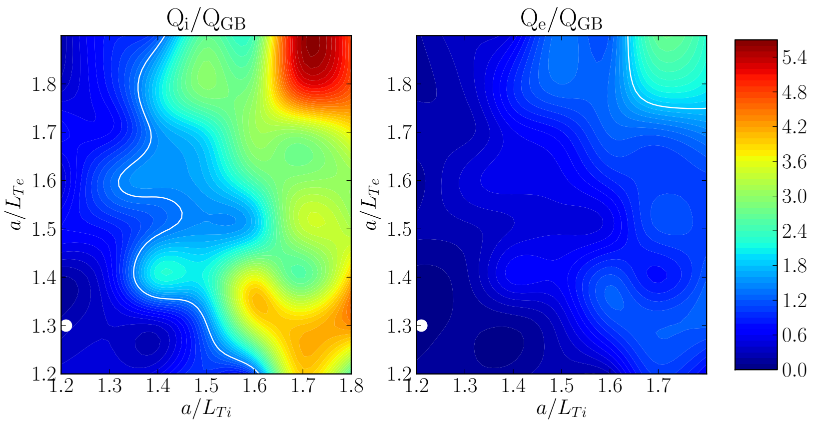

GYRO flux map at $r/a = 0.8$ as a function of a/L_{Te}, a/L_{Ti} for an ITER hybrid scenario. White contour line shows critical values of $Q_i/Q_{\rm GB} = 1.4$ (left), $Q_e/Q_{\rm GB} = 1.8$ (right) predicted by TGYRO to obtain net power balance. White dots show TGLF gradients at which balance is obtained. Thus GYRO predicts markedly higher gradients to produce the same fluxes required to achieve power balance.

In this work, we show that improvements in predicted ITER performance may be realized by accounting for stabilization from self-generated zonal flows. Prior transport modeling has shown that acceptable ITER confinement requires core ion/electron energy fluxes to be on the order of a single gyroBohm; that is, $Q_e/Q_{\rm GB}, Q_i/Q_{\rm GB} \simeq 1$, where $Q_{\rm GB} \doteq \rho_s^2 c_s/a$ is the gyroBohm energy flux, and ρ_s is the ion-sound gyroradius. This implies proximity to the linear threshold, and GYRO [1] simulations show that nonlinearly-generated zonal flows reduce the steady-state flux in this regime in comparison with TGLF levels. Indeed, we observed that for steady-state ITER profiles predicted by TGLF [2], GYRO simulations exhibit complete turbulence quenching. This observation suggests that accounting for zonal-flow stabilization in TGLF predictions of ITER may lead to improved ITER performance estimates. We report on quantitative assessments of the performance improvement expected when stabilization from nonlinear flows is added via gyrokinetic re-tuning of TGLF in the near-threshold regime. Simulations are based on TGYRO [3] modeling of an ITER hybrid DT scenario with approximately 45 MW of auxiliary power, hollow q-profile, equal D/T fractions, and ^{4}He ash. Impurity (Ar,Be,W) and fast-ion populations are also considered. Alpha heating to electrons and ions, collisional exchange, and electron radiation are computed self-consistently. Neoclassical transport for all species is computed by NEO [4] without approximation. TGYRO-GYRO simulations of the TGYRO-TGLF scenario show that turbulence is quenched inside $0.1 \le r/a \le 0.8$, with the implication that improved performance is expected after accounting for these effects in TGLF. Work supported by the U.S. Department of Energy under Grant No. DE-FG03-95ER54309.

References

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