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固定熱流および固定勾配駆動ITG乱流の大域的ジャイロ運動論シミュレーション

Fixed-flux and fixed-gradient global gyrokinetic simulations of ITG turbulence

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In this study, systematic comparisons among several gyrokinetic simulation models, i.e., a global full-f fixed-flux(FF), a global delta-f fixed-gradient(FG), and a local fluxtube(FT) models, have been carried out by using a full-f Eulerian gyrokinetic code GT5D[1, 2] and a local fluxtube code GKV[3], and then, plasma-size(ρ*) and collisionality(ν*) dependences of ion temperature gradient(ITG) turbulent transport have been investigated. In order to emulate a delta-f simulation in GT5D, a FG source model are newly implemented by extending an adaptive momentum source model in Ref. [4]. It is emphasized that in the FG model, artificial source and sink inside the plasma compensate local temperature variations, and they account for ~85% of the total power balance.

The ν*-dependence on turbulent transport at far above marginal states are verified through the inter-model comparison. The weak ν*- dependence of the heat diffusivity, which has also been observed in L-mode discharges[5], has been confirmed in the FF and FT models. In the FG simulations, converged results are obtained for $\nu^* \leq 0.0143$ that is regarded as an asymptotic collisionless limit[6], while the transport enhancement in proportion to ν* is observed above this threshold. The detailed analysis has highlighted a problematic behavior of the conventional FG source model in the high ν*- regime, where the profile relaxation towards the collisional equilibrium may cause a spurious heating as ν* increases.

The ρ*-scan with the FF simulations is extended towards the local limit regime($\rho^{*-1}>300$), where the heating power is simultaneously scaled with the plasma size(cf. Ref. [4, 7]). The Bohm like heat transport associated with the formation of stiff temperature(T_i) gradient profiles bounded by near critical value R_0/L_{Ti}~6.5 has been found even in the local limit regime, where the profile shear effects become significantly weak[see. Fig. 1]. Small-scale avalanches bounded by the radial scale of zonal flows and the large bursty behavior, which propagates over significant radii across zonal flows, are identified. It has been clarified that despite the stiff-T_i profiles with similar mean-R_0/L_{Ti} (FT results give only ~7% difference in the heat diffusivity), local variations of power balance before bursts can produce significantly different super-critical states of R_0/L_{Ti} leading to the Bohm like burst amplitude in the heat diffusivity.

Close comparisons of the statistical properties (PDF, frequency spectra) and zonal flows among FF, FG, and FT models have shown many similarities, but it is emphasized that the local power balance dynamics, which is important for the Bohm like heat transport and the profile stiffness, is essentially different among these models.

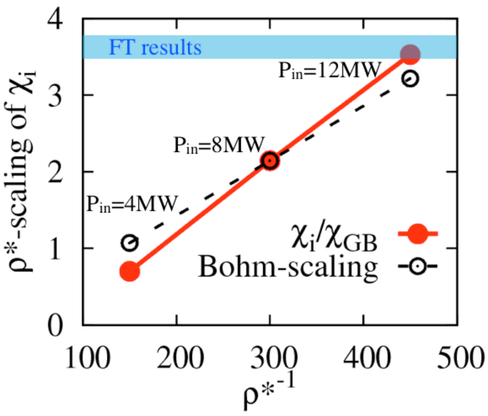

Fig. 1 Bohm like ρ*-scaling of the heat diffusivity in the FF simulation, where P_{in} denotes the heating power. The shaded region shows the transport level obtained from FT simulations for stiff T_i-gradient parameters R_0/L_{Ti}=6.20(ρ^{*-1}=300), 6.55(ρ^{*-1}=450).

References

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