§22. Kinetic and Fluid Simulations of the Collisionless Slab Ion Temperature Gradient Driven Turbulence

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In recent years, gyrokinetic and gyrofluid (or gyro-Landau-fluid) simulations of plasma turbulence driven by microinstabilities such as the ion temperature gradient (ITG) mode have been actively done in order to predict the anomalous transport coefficients in magnetically confined plasmas from the first principle. In the gyrofluid model, some closure relations are assumed to construct a trucated system of fluid equaitions from the gyrokinetic equation and their validity in nonlinear or turbulent regimes is not clear because conventional gyrofluid closure models such as the Hammett-Perkins (H-P) model[1] are originally derived so as to accurately reproduce gyrokinetic dispersion relations for linear modes. In fact, there exist some cases, in which the gyrokinetic and gyrofluid simulations show disagreements in their nonlinear results such as the saturated fluctuation levels and the turbulent transport coefficients. In our previous work,[2] we have presented the nondissipative closure model (NCM), which takes into account the time reversal symmetry of the collisionless kinetic equation. The NCM relates the parallel heat flux to the temperature and the parallel flow in terms of the real-valued coefficients in the unstable wave number space. The NCM was derived such that the closure relation is valid both for the unstable normal-mode solution and its complex-conjugate solution as well as for any linear combination of these solutions. A fluid system of equations with the NCM used reproduce the exact nonlinear kinetic solution of the three-mode ITG problem[3] while the H-P model fails in representing that solution. Then, the next question is whether the NCM can successfully describe strongly turbulent states of collisionless kinetic systems with a higher number of degrees of freedom. In the present work, in order to answer this question, we do both fluid and kinetic simulations of the two-dimensional slab ITG turbulence and investigate how accurately the fluid simulation using the NCM or the H-P model can reproduce results of the collisionless kinetic simulation under the same conditions. Here, in order to avoid the complexity brought about by the zonal flow and get finite turbulent transport, we artificially suppress the zonal flow component of the fluctuations.

Figure 1 shows the normalized perpendicular heat diffusivity $\chi/(\rho_i^2 v_t/L_n)$ as a function of normalized time $v_t t/L_n$ obtained by the kinetic and fluid (NCM, H-P) simulations. It is found from the kinetic simulation that the phase relation between the potential and the distribution function for the most unstable mode is different from that predicted by the linear unstable eigenfunction and is better described by the NCM than by the H-P model. This fact explains a reason for the result shown in Fig.1 that, in the steady turbulence state, the turbulent thermal diffusivity χ obtained by the H-P model is significantly larger than χ given by the NCM and that the latter is closer to χ found in the kinetic simulation.

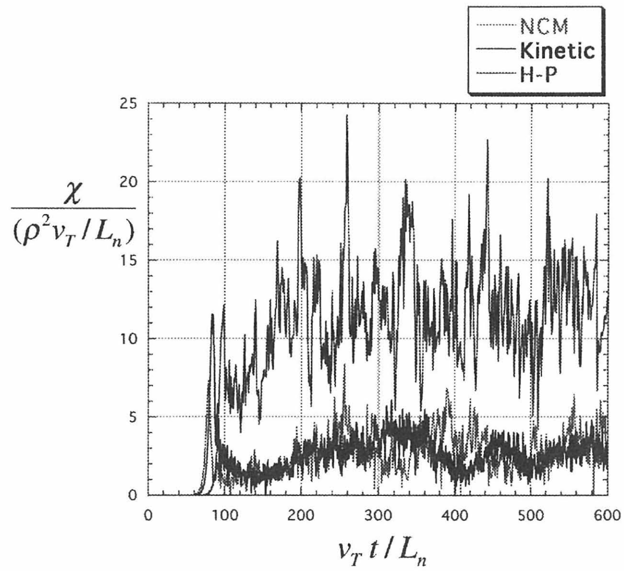

Fig.1. Normalized perpendicular heat diffusivity $\chi/(\rho_i^2 v_t/L_n)$ as a function of normalized time $v_t t/L_n$ obtained by the kinetic and fluid (NCM, H-P) simulations.

References
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2) Sugama, H., Watanabe, T.-H., and Horton, W., Phys. Plasmas **8** (2001) 2617.
3) Watanabe, T.-H., Sugama, H., and Sato, T., Phys. Plasmas **7** (2000) 984.