§14. Extension of Gyrokinetic Simulation Code GKV and its Application to Plasma Turbulent Transport

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A variety of gyrokinetic simulation codes have been developed as a powerful tool for invensigating the turbulent transport in magnetically confined plasma, and are utilized not only for theoretical studies but also for experimental analyses. The flux tube gyrokinetic code, GKV, was first developed at NIFS, and is continuously developed under collaborations with JAEA and Nagoya University. While the physical model in the original version was limited to a single species case with the electrostatic approximation, the GKV code has been extended step by step, so as to incorporate the two and three-dimensional field configurations reconstructed from experimental data, the ion and electron species, the electromagnetic fluctuations, and the multiple ion species. In FY2014, we have developed a novel collision operator applied to multi-species ions with different temperatures, and also implemented a new numerical method to efficiently deal with turbulent fluctuations elongated along field lines. In this report, we describe the new simulation method, "flux tube train model", and its application to the ion temperature gradient turbulence, which was also published as Ref. 1).

In local flux tube simulations of drift wave turbulence in toroidal systems, turbulent fluctuations may elongate along field lines over one poloidal turn. It is often found in case with low magnetic shear, or in case close to the marginal stability limit. In order to avoid artificial enhancement of turbulent correlations, it was proposed to extend the simulation domain along field lines over several poloidal turns. However, it leads to numerical difficulties such as a severe CFL condition and a symmetry breaking. The flux tube train model has been developed as a remedy for the conventional method.

Basic idea of the flux tube model is quite simple but useful, where a series of flux tubes are connected with a twisted boundary condition. This model can explicitly preserve the symmetry for image modes in the ballooning representation. Fig. 1 shows comparison of the conventional single flux tube (upper) and the flux tube train (lower) simulations, where the potential fluctuations of the ion temperature gradient turbulence are plotted in the z-k_x space. It is clearly found that the radial wave numbers of image modes increase with θ in the single flux tube case but remain constant in the flux tube train model. Comparison of the ion heat transport is also shown in Fig. 2 by changing the flux tube length or the number of cars in a train. The both results agree well but the single flux tube simulation faces the numerical difficulty for N_θ=16 while the numerical convergence against the number of cars (N_t) is confirmed by the flux tube train model. The obtained results highlight the numerical advantage of the new method.

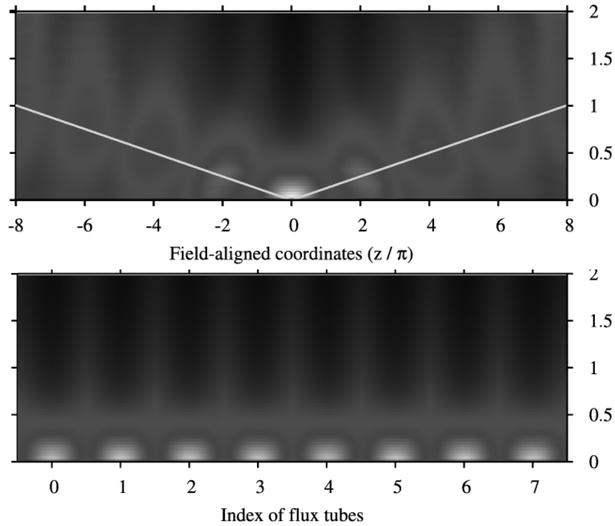

Fig. 1. Color contour of potential fluctuation intensity in z-k_x space for cases using a single flux tube (upper) and a flux tube train model (lower) [T.-H. Watanabe, H. Sugama, A. Ishizawa, and M. Nunami, Phys. Plasmas **22**, 022507 (2015)].

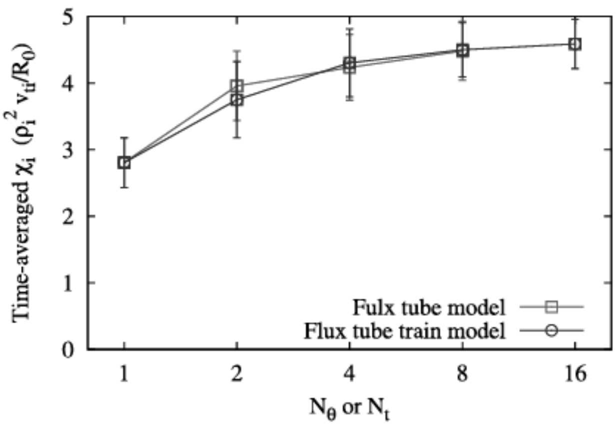

Fig. 2. Comparison of the ion heat transport coefficient obtained by GKV simulations of ion temperature gradient turbulence for cases using a single flux tube and a flux tube train model [T.-H. Watanabe, H. Sugama, A. Ishizawa, and M. Nunami, Phys. Plasmas **22**, 022507 (2015)].

1) T.-H. Watanabe, H. Sugama, A. Ishizawa, and M. Nunami, Phys. Plasmas **22**, 022507 (2015).