9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

The nonmodal kinetic theory of the macroscale convective flows of magnetized plasma, generated by the inhomogeneous microturbulence

V. S. Mykhaylenko[1], V. V. Mykhaylenko[1], Hae June Lee[2]
[1]Plsma Research Center, Pusan National University, Busan, South Korea
[2]Department of Electrical Engineering, Pusan National University, Busan, South Korea
e-mail(speaker): vsmikhailenko@pusan.ac.kr

In this report, we present the two-scale non-modal approach to the kinetic theory of the microturbulence of a plasma, inhomogeneous on the macroscales across the confined magnetic field. This approach reveals the effect of the formation of the macroscale convective flows of such a plasma caused by the interaction of ions with inhomogeneous microturbulence. The developed theory displays that the macroscale convective flows generated by the microturbulence inhomogeneous on the macroscale are the inherent components in the temporal evolution of the inhomogeneous microturbulence. It is found that the velocities of the electron convective flows are negligible small and the macroscale convective flow transports mostly the ions. Any microscale perturbation in the radially inhomogeneous flows, which before the development of the inhomogeneous non-diffusive convective flow had a plane wave structure, experiences the continuous distortion in the flow and becomes the sheared-compressed mode with time dependent structure. This distortion grows with time and forms a time-dependent nonmodal process, which affects the microturbulence and the average ion distribution function. The derived nonmodal ion kinetic equation, that dertermines temporal evolution of the microscale perturbation of the ion distribution function in the macroscale convected flows, and the integral equation for the potential of the microturbulence, that governs the temporal evolution of the microscale turbulence in the inhomogeneous non-diffusive convected flows, developed by the microturbulence itself, are the basic equations of the temporal evolution of the inhomogeneous microturbulence.

The theory of the slow macroscale response of a bulk of ions on the development of the non-diffusive convective flows is presented. This theory contains 1) the nonmodal quasilinear theory, which governs the slow temporal evolution on the macroscales the ion and electron distribution functions, resulted from the interactions of ions and electrons with ensemble of the sheared-compressed microscale waves with random phases, 2) the self-consistent theory of the slow temporal evolution of the macroscale electrostatic potential of the plasma response on the developed macroscale convective flow. The integral equation for the macroscale potential of the plasma response on the convective flows is the basic equation of the stability theory of the convective flows against the development of the secondary macro/meso scale instabilities of a plasma with inhomogeneous macroscale convective flows developed by the microturbulence. The application of the developed theory to the ion temperature gradient driven microturbulence is presented.

This work was supported by National R&D Program through the National Research Foundation of Korea (NRF) (Grant No. NRF-2022R1A2C101280826)