Spatio-temporal dynamics of turbulence coupling with zonal flows

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Formation mechanism of spatial profile of turbulence is one of important subjects in fusion plasma research. There are mechanisms to determine the spatial profile of the turbulence; one is the propagation, such as the avalanche and turbulence spreading [1], and the other is the interaction with the sheared flows, where the effects of flow shear [2] and of flow curvature [3] have been theoretically predicted. Experimental observations on the spatial profiles of turbulence within the scale of flow shears have been reported [4]. Therefore, a unified model that can predict the spatial structure of turbulence, including the mechanisms of the propagation and the interaction with the sheared flows, is required.

In this study, we investigate the phase-space dynamics of turbulence coupling with the zonal flows, based on the wave-kinetic framework. We focus on the oscillatory branch of zonal flows, which is called geodesic acoustic modes (GAMs), on which there are many experimental observations. Spatio-temporal structures of the turbulence and GAMs are obtained numerically. Due to the turbulence trapping by the GAM [5], the turbulence is accumulated at regions where the curvature of the GAM (spatial-second-derivative of the flow) is negative, and the turbulence is suppressed at the positive curvature region. The roles of the flow shear and curvature on the turbulence spatial profile are illustrated. The phase relation is sustained with the propagation of the GAM [6]. Hence, there appear a new global characteristic velocity for turbulence propagation, in addition to the local group velocity and that of the turbulence spreading.

References

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