Evolving the Ion Temperature Gradient driven turbulence with test modes

V. Baran[1,2], M. Vlad[1], and F. Spineanu[1]

[1]*National Institute for Laser, Plasma and Radiation Physics, Magurele, Bucharest, 077125, Romania*
[2]*Faculty of Physics, University of Bucharest, Magurele, Bucharest, 077125, Romania*

The analytical treatments of turbulence are severely outnumbered by the numerical simulations, due to the complexity of this strongly nonlinear process. In the case of magnetically confined plasmas, the particle and energy transport properties are directly influenced by the low frequency drift type turbulence, whose nonlinear evolution exhibits large scale correlations and generation of zonal flow modes.

The first semi-analytical methods capable of reaching beyond the quasi Gaussian transport stage are the decorrelation trajectory method and the nested sub-ensemble approach [1,2], being able to naturally account for the trajectory trapping leading to quasi coherent structures. On this basis, it is possible to perform a study of the test modes on top of a turbulent plasma background [3].

In this work we investigate, within the framework of the test modes approach, the evolution of the ion temperature gradient (ITG) driven turbulence in slab geometry. Starting from a drift kinetic picture, the growth rates of the test modes are obtained from a dispersion relation altered with respect to the quiescent plasma case by the statistical averaging procedure of the ion propagator over the background turbulence configurations. In turn, the growth rates indicate the tendencies of evolution of the spectrum of the background fluctuations. Through this kind of self-consistent iterative procedure [4] we gain new insights into the nature of the emerging complex nonlinear processes. The effects of the density gradient are also studied.

A new mechanism of generation of zonal flow modes (zfm) was found. It does not involve the Reynolds stress of the electric drift velocity fluctuations, nor the combined action of ion eddying and potential drift, but is due to the ion diffusion along the ion temperature gradient. The radial diffusion has dual role on zfm. Besides the damping effect produced by ion spreading, the background turbulence determines the amplification of these modes. The amplification effect yields from the advection of the temperature gradient with the stochastic ExB velocity of the background turbulence modulated by the potential of the mode. More precisely, the Lagrangian correlation of the stochastic velocity with the trajectory leads to a radial average Lagrangian velocity that adds to the diamagnetic velocity and yields unstable modes with zero poloidal wave numbers. The zfm turbulence contributes to the damping of the ITG turbulence through the increase of poloidal diffusion coefficient.

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References

[1] M. Vlad, F. Spineanu, J. H. Misguich, R. Balescu, Phys. Rev. E 58, 7359 (1998)
[2] M. Vlad, F. Spineanu, Phys. Rev. E 70, 056304 (2004)
[3] M. Vlad, Phys. Rev. E 87, 053105 (2013)
[4] M. Vlad, F. Spineanu, New J. Phys. 19, 025014 (2017)