Evolution of plasma turbulence beyond the quasilinear regime; a semi-analytical study

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The evolution of turbulence in magnetically confined plasmas is a complex problem that is not completely understood in spite of a huge amount of work. Low-frequency drift type turbulence, which has a significant influence on plasma confinement, is extensively studied especially in connection with fusion research. Most of the studies that go beyond the quasilinear stage are based on numerical simulations or on simplified models. Numerical simulations show a complex nonlinear evolution with generation of large scale correlations, increase of order, appearance of zonal flow modes and nonlinear damping of turbulence. Zonal flow modes and their effects on turbulence damping and on improved confinement is presently a very active research topic. The generally accepted image of zonal flow modes and drift turbulence evolution is of predator prey type.

We present a first principle semi-analytical approach for the study of drift turbulence in magnetically confined plasmas. This is a Lagrangian semi-analytical method that is able to describe the complex evolution of turbulence beyond the quasilinear regime. The method is based on the evaluation of the statistics of trajectories (characteristics of the evolution equation) using semi-analytical approaches (the decorrelation trajectory [1] and the nested subensemble [2] methods. This is far from a Gaussian process due to ion trapping or eddying in the structure of the turbulent potential.

We study linear modes on turbulent plasma with the statistical characteristics of the potential considered known. The collisionless kinetic drift turbulence in slab geometry is considered. Analytical expressions are derived, which approximate the growth rates and the frequencies of the test modes as functions of the characteristics of the background turbulence. They provide an image of turbulence evolution.

We show that there is a sequence of processes, which appear at different stages of evolution as transitory effects and that the drift turbulence has an oscillatory evolution [3]. A different perspective on important aspects of the physics of drift type turbulence in the strongly non-linear regime is deduced. There is no causality relation between zonal flow modes and drift turbulence damping. Both effects are generated self consistently in the nonlinear evolution of drift turbulence. The influence produced by the zonal flows on the drift type modes is only indirect, through the diffusive damping. The predator-prey paradigm is not sustained by these results, although there is time correlation between the maximum growth rate of zonal flow modes and the damping of the drift modes. The main role in these processes is shown to be played by ion trapping.

[1] M. Vlad, F. Spineanu, J. Misguich, R. Balescu, Phys.Rev.E 58 (1998) 7359

[2] M. Vlad and F. Spineanu, Phys. Rev. E 70 (2004) 056304

[3] M. Vlad, *„Ion stochastic trapping and drift turbulence evolution”*, Phys. Rev E (2013), submitted.