§ 19. Bifurcation and Phase Diagram of Turbulence Constituted from Three Different Scale-Length Modes

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Cases where three kinds of fluctuations having the different typical scale-lengths coexist are analyzed, and the statistical theory of strong turbulence in inhomogeneous plasmas is developed. Statistical nonlinear interactions between fluctuations are kept in the analysis as the renormalized drag, statistical noise and the averaged drive. The nonlinear interplay through them induces a quenching or suppressing effect, even if all the modes are unstable when they are analyzed independently. Variety in mode appearance takes place: one mode quenches the other two modes, or one mode is quenched by the other two modes, etc. The bifurcation of turbulence is analyzed and a phase diagram is drawn. Phase diagrams with cusp type catastrophe and butterfly type catastrophe are obtained. The subcritical bifurcation is possible to occur through the nonlinear interplay, even though each one is supercritical turbulence when analyzed independently. Analysis reveals that the nonlinear stability boundary (marginal point) and the amplitude of each mode may substantially shift from the conventional results of independent analyses.

In order to discriminate three kinds of different scale lengths, we use the symbol m, l, h for the mode of the longest scale length, the intermediate scale length, and the shortest scale length, respectively.

The coupled equations are given for the macro, semi-micro and micro modes are derived by use of the statistical theory in [1] and is given in [2]. The coupled equations are solved, and conditions are searched for, where fluctuations with different scale lengths are excited. Summarizing these studies of

solutions, the phase diagram is given in Fig.1. Where the number '0' is written, one or two kinds of modes are quenched. In Fig.1, 'i+j' means that there are number of i solutions belong to the upper branch of the macro mode and j solutions to the lower branch of the macro mode, respectively.

We have analysed the nonlinear interplay between three kinds of modes in turbulent plasmas. The basic mechanisms of these nonlinear interactions are generic. The subcritical excitation owing to the presence of fluctuations of other scale length can be applied to the sudden appearance of the "events" or "collapse phenomena", such as sawtooth activities etc. Furthermore, the basic concept can be used for the systems of complexity, which requires the further study.

Fig.1 Phase diagram on the driving parameters for the macro and micro modes, i.e., on the (D^l, D^h) plane. Other parameters are fixed constant. Expanded view in given in the lower figure. (See [2] for details.)

Reference

- [1] Itoh S-I and Itoh K: Plasma Phys. Contr. Fusion **43** (2001) 1055.
- [2] Itoh S-I, Kitazawa A, Yagi M and Itoh K: Plasma Phys. Control. Fusion **44** (2002)1311