Lyapunov exponents and control of spatiotemporal chaos and transport in helical magnetic devices

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Analysis of simulation results of gyrokinetic Vlasov simulations of the ion temperature gradient turbulence demonstrates that fluctuations of electrostatic potential, both in the standard and the inward shifted configurations, exhibit spatiotemporal chaos [1]. For spatiotemporal chaotic systems both the Lyapunov dimension D_L and the Kolmogorov-Sinai (KS) entropy h are extensive quantities (i.e. D_L and h increase linearly with the system size). In Fig. 1 the sum of Lyapunov exponents $\sum_{k=1}^{i}\lambda_k$ is presented as a function of i for various sizes of the system so that the Lyapunov dimension may be obtained from the intersection with the horizontal axis and the KS entropy may be extracted from the maximum of the curve. The Lyapunov dimension and the KS entropy of the standard shifted configuration (blue curves) are always greater than for the inward shifted one (red curves) and that D_L and h are extensive quantities. A direct consequence of this property has a deep impact on transport properties so that enhanced zonal flow generation in the inward shifted case is accompanied by transport reduction which we show is a direct consequence of chaos suppression. Denoting by D the number of degrees of freedom of the system, due to the fractal structure of phase space of the system in two configurations there is a dimension loss ΔD when the system evolves in each configuration. This quantity may be analytically derived and transport properties such as thermal diffusivity may be expressed in terms of it. A direct relationship between Lyapunov exponents, dimension loss and transport properties is derived establishing a deep relationship which may of great importance for control of chaos in magnetic confinement systems.

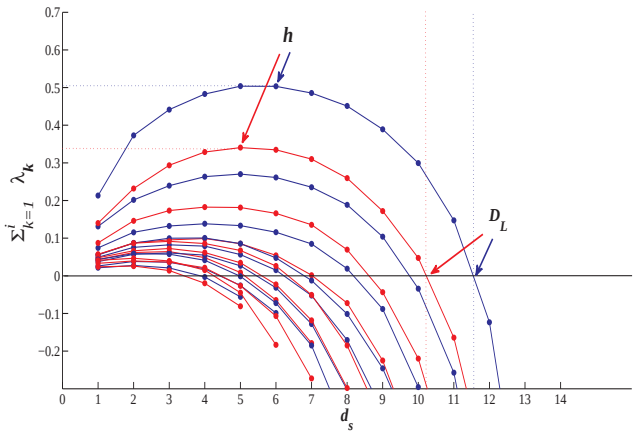

Fig. 1 The sum of Lyapunov exponents of the standard configuration dynamics (blue) and inward shifted dynamics (red) as a function of the system size d_s. The Lyapunov dimension D_L and the Kolmogorov-Sinai entropy h may be estimated from the diagrams.

[1] M. Rajković, T.-H. Watanabe and M. M. Škorić, Phzsics of Plasmas (in press).