Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

PEM029-18 Room: 303 Time: May 25 14:44-14:57

Self-organized critical transport and entropy dynamics in turbulent plasmas

Kenji Imadera[1*], Yasuaki Kishimoto[1], Jiquan Li[1]

[1]Kyoto University

Turbulent transport in magnetically confinement fusion plasmas exhibits various prominent features characterized by different time and spatial scales. Zonal modes, such as zonal flow and pressure, which are poloidally and toroidally symmetric macro-scale structures non-linearly generated from micro-scale turbulence, are found to play an important role, leading to the regulations in turbulent transport and resultant energy confinement. These zonal modes are considered to tightly link to the non-local and/or global natures in turbulent transport, which are not simply explained by the Gaussian statistics such as intermittent transport, turbulent spreading and avalanche event, etc. Another example is the self-organized critical (SOC) transport [1] where turbulence provides a strong constraint to the relaxation process, leading the temperature profile to the self-organization and to self-similar relaxation. In order to characterize such complex transport dynamics, entropy in phase space which connects micro-scale turbulent structure to macro-scale thermo-dynamic quantities has been introduced as one of the measures [2]. However, it has been treated as a global quantity which is integrated over phase space, so that the non-local nature of transport is hardly discussed.

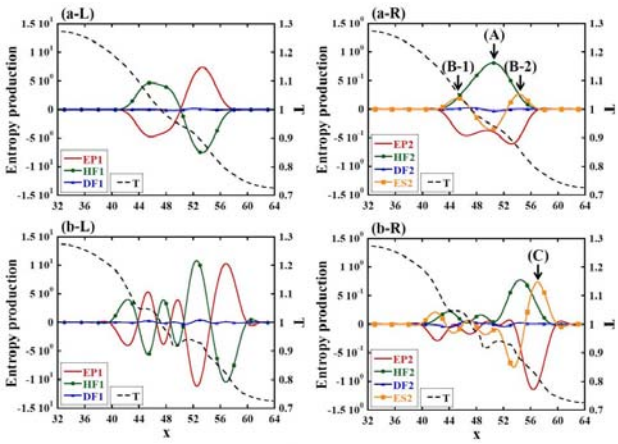

Fig .1

To address this problem, we extend the entropy balance equation by keeping the dynamics in radial direction. The equation has a hierarchical structure with respect to the fluctuation where the first order equation corresponds to that of the thermodynamics/ fluid entropy, whereas the second order one to that of the phase space entropy resulting from higher order velocity moment. Note that the second order equation includes, in addition to the effect of the zonal flow, the divergence of the second order entropy flux to radial direction, which represents the turbulent spreading.
Here, we investigate the entropy dynamics in the ITG turbulence with global profile relaxation based on gyrokinetic Vlasov simulation in slab geometry. The entropy balance relation in the first and second order entropy equations at two different time scales near the ITG mode saturation is shown in Fig. 1 in left and right hand side column, respectively. The entropy productions related to the turbulent fluctuation (EP1), heat flux (HF1) and density flux (DF1) for the first order equation are shown in Fig. 1 (L) and those for the second order equation, i.e., (EP2), (HF2), (DF2) and also the entropy spreading (EC2) are shown in Fig. 1 (L). The temperature profile is also illustrated.
In Fig. 1 (a-L), which is in the linear phase, (EP1) locally appears and mainly balances with (HF1), then the temperature relaxation starts. Note that (DF1) is found to be weak. (EP2) localizes in the

region where the temperature gradient is steep and ITG mode is firstly excited (marked by (A)). Interestingly, (EP2) radially expands from the region (A) to (B1) and (B2) due to entropy spreading (ES2), as seen in Fig.1 (a-R). The local flattening of the temperature profile triggers another steepening in both sides, which gives rise to the subsequent instability and flattening. This is found from the fact that the number of wave in radial direction related to the term (EP1) and (HF1) increases in Fig.1 (b-L), which is the phase near the saturation. Correspondingly, the second order entropy increases in wider region and (EP2) predominantly balances with entropy spreading (ES2) in outer region, which form the propagation front of the entropy as seen in Fig.1 (b-R). Thus, it is found that such an avalanche dynamics accompanies second order entropy spreading and the profile globally relaxes to the marginally stabilized one where entropy production disappears in whole region.

[1] Y.Kishimoto, T. Tajima, W. Horton, M. J. LeBrun and J. Y. Kim, Phys. Plasmas 3 1289 (1996).
[2] T.-H. Watanabe and H. Sugama, Phys. Plasmas 9, 3569 (2002).

Keywords: self-organized critical transport, phase space entropy, turbulent spreading, gyrokinetic simulation