§30. Study on Plasma Turbulence Based on Shell Model

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The shell model[1,2] is extended to describe plasma turbulence. Using this model, the electromagnetic plasma turbulence is investigated. The model consists of 1-dimensional three feild equations:

$$\left(\frac{d}{dt} + \nu k_n^2\right) u_n = A k_n [u_{n-1}^{*2} - b_{n-1}^{*2} - h(u_n^* u_{n+1}^* - b_n^* b_{n+1}^*)] + B k_n [u_n^* u_{n-1}^* - b_n^* b_{n-1}^* - h(u_{n+1}^{*2} - b_{n+1}^{*2})] + i k_n b_n + \theta_n \quad (1)$$

$$\left(\frac{d}{dt} + \eta k_n^2\right) b_n = A k_n h(u_{n+1}^* b_n^* - u_n^* b_{n+1}^*) + B k_n (u_n^* b_{n-1}^* - u_{n-1}^* b_n^*) + i k_n u_n \quad (2)$$

$$\left(\frac{d}{dt} + \chi k_n^2\right) \theta_n = A k_n (u_{n-1}^* \theta_{n-1}^* - h u_n^* \theta_{n+1}^*) + B k_n (u_n^* \theta_{n-1}^* - h u_{n+1}^* \theta_{n+1}^*) + S u_n \quad (3)$$

where u_n represents the fluctuating velocity field, b_n, the fluctuating magnetic field and θ_n, the fluctuating temperature field. The system is normalized by using the system size L and the Alfven time L / v_A. In the convective nonlinearity in Eqs.(1)-(3), only the nearest neighbor interaction is kept. S is defined by $S = R_a / (Q P_m)$ where $R_a = \alpha \beta g L^4 / (\kappa \nu)$ is the Rayleigh number, $Q = b_0^2 L^2 / (\mu_0 \rho_0 \eta \nu)$, the Chandrasekhar number, $P_m = \eta / \kappa$, the magnetic Prandtl number, respectively. For the typical parameters of high temperature plasma, the viscosity due to the Coulomb collision gives the estimate: $R_a \approx 10^{22}$, $Q \approx 10^{17}$, $P_m \approx 10$, $S \approx 10^4$.

Figure 1 shows the time evolution of flow energy (red), $E_u = \frac{1}{2}\sum |u_n|^2$ and internal energy (blue), $E_\theta = \frac{1}{2}\sum |\theta_n|^2$. Parameters are chosen as $A = B = i$, $h = 2$, $\nu = \eta = \chi = 10^{-6}$. In these parameters, the relation $|u_n| \approx |b_n|$ holds. It is found that flow energy stays at some energy level for a moment, then it starts to increase and reaches at the higher energy level. The bursting behavior of internal energy is observed in the phase of increase of flow energy.

Figure 2 shows the power spectra of electromagnetic energy (red) and internal energy (blue) at $t = 300$ (quasi-steady state), which are given by $E_b(k_n) = |b_n|^2 / (2k_n)$ and $E_\theta(k_n) = |\theta_n|^2 / (2k_n)$. It seems that $k_n^{-5/3}$ law does not hold for $E_b(k_n)$ or $E_u(k_n)$ and $E_\theta(k_n)$. The behavior of this model is differnt from the results obtained by the model without Alfvenic effect [2] and the model without thermal convection but with Alfvenic effect [3].

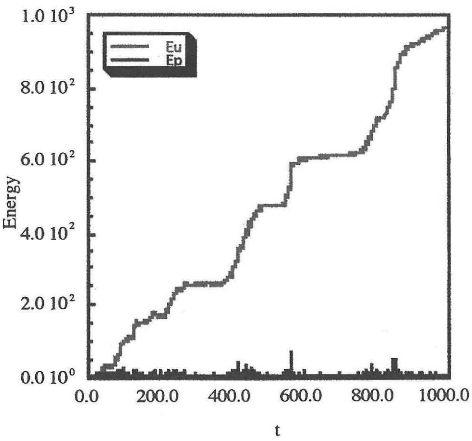

Fig.1 the time evolution of fluctuating energies.

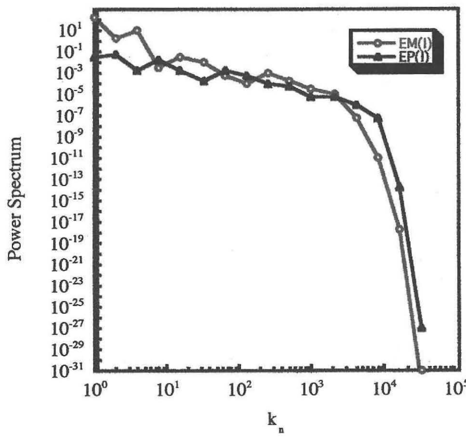

Fig.2 the power spectrum of energy at $t = 300$.

The model in which the drift wave effec is incorporated should be examined as a future work.

Reference

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2) A. Brandenburg, Phys. Rev. Lett. **69** (1992) 605.
3) D. Biskamp, Chaos, Soliton & Fractals **5** (1995) 1779.