§36. Self-Sustained Plasma Turbulence due to Current Diffusion

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Recently, a theoretical method of self-sustained turbulence has been proposed. The confirmation by use of the direct simulation is obtained [1].

We study the high-aspect-ratio, toroidal helical plasma with magnetic hill and strong magnetic shear in a slab model. The reduced set of equations for the electrostatic potential ϕ, pressure p, and current J are employed as:

$$\frac{d}{dt}\nabla_{\perp}^{2}\phi = ik_{y}sxJ - i\alpha k_{y}p + \mu_{\perp c}\nabla_{\perp}^{4}\phi \qquad (1)$$

$$\frac{d}{dt}J = -ik_{y}sx\,\phi + \lambda_{c}\nabla_{\perp}^{2}J \qquad (2)$$

$$\frac{d}{dt}p = -ik_{y}\phi + \chi_{c}\nabla_{\perp}^{2}p \qquad (3)$$

The main magnetic field is in the z-direction, and the x-axis is in the direction of the pressure gradient. s is the shear parameter and α is the combination of the pressure gradient and bad curvature. Length and time are normalized to the collisionless skin depth and the poloidal Alfven transit time, respectively. The transport coefficients $\mu_{\perp c}$, λ_c, χ_c are the collisional viscosity, current diffusivity and thermal diffusivity, respectively.

Direct nonlinear simulation was performed. The two-dimensional turbulence has been calculated in a system of the size $|x| < L_x$ and $|y| < L_y$. (Parameters in the simulation were: $\mu_c = \chi_c = 0.2(c/a\omega_p)^2$, $\mu_{ec} = 0.01(c/a\omega_p)^2$, $s = 0.5$, $L_x = 40(c/a\omega_p)$ and $L_y = 6.4\pi(c/a\omega_p)$.) For this system, the linear stability boundary is given as $\alpha_c \simeq 0.4$. Nonlinear excitation of the fluctuations was confirmed in the simulation. Figure 1 summarizes the nonlinear stability boundary in the gradient-fluctuation space. Figure 2 compares the simulation and theory of the turbulent-driven transport. The subcritical nature and self-sustainment are clearly demonstrated.

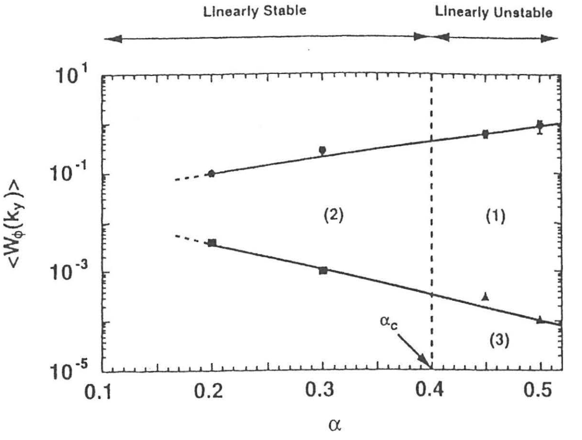

Fig.1 Nonlinear stability boundary. In regions (1) and (2), nonlinear instability takes place.

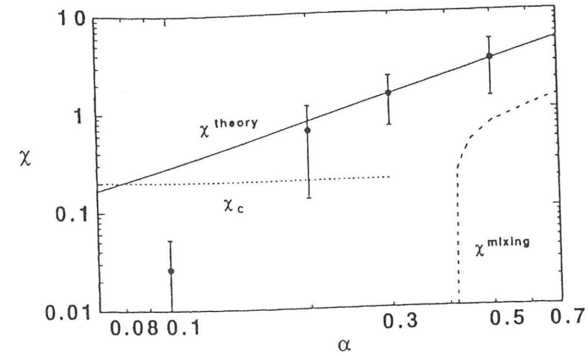

Fig.2 Thermal diffusivity vs α. Solid line indicates the nonlinear theory, and dashed line shows mixing-length estimate.

1) M. Yagi et al., Phys. Plasmas 2 (1995) 4140.