**Plasma Edge Theory in Fusion Devices**

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**1 Introduction**

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**2 Model Equation**

The 4-field reduced MHD model consists of vorticity equation, Ohm’s law, parallel momentum equation, and density evolution equation [1, 2]. The poloidal Alfv´en time and the plasma minor radius are used for the normalization. In the circular tokamak geometry (r, θ, ζ), these are given by



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where *d/dt* = *∂/∂t* + [**, ], ∇|| = ∇||(0) − [*A*, ], [*f*, *g*] = (*∂f/∂r*)(*∂g/r∂*) − (*∂f/r∂*)(*∂g/∂r*), ∇2⊥ =(*∂/r∂r*)(*r∂/∂r*) + *∂*2*/r*2*∂*2, *U* = ∇2⊥*Fi*, *Fi* = ** + *ip*, *Fe* = **−*ep*, *J* = ∇2⊥*A*, ** = *Te/Ti*, ** = *c*/(*api*), *i* = **/(1 + τ ) , *e* = **/(1+**) , **ˆ = **/(1 + **) .

**3 Simulation Result**

3.1 Nonlocal Transport by Convection

In this simulation, the cylindrical source is applied at *t* = 960 after saturation of the resistive ballooning turbulence, which is excited in the peripheral region. In this phase, the flux-averaged density profile is gradually increasing due to the particle source. Then, the source is switched off at *t* = 1200. Figure 1 shows the time evolution of internal energy for each Fourier mode.



**Fig. 1** Time evolution of internal energy for each Fourier mode. (0, 0) and (±1, 0) modes are dominant.

3.2 Interaction between (0, 0) and (±1, 0) modes

In this subsection, the detail analysis is carried out based on the energy balance equations for *p*(*r*, 0, 0) and *p*(*r*, ±1, 0). Figure 2 and 3 show the radial profile of each term in RHS of Eqs. (8) and (9) at *t* = 1350 . It is shown that the convective nonlinearity (RHS1) in Eq.(8) is dominant (Fig. 2), which contributes the nonlocal transport, via three wave coupling (1, 0) + (−1, 0) → (0, 0) . On the other hand, the toroidal coupling (RHS2) in Eq. (9) mainly drives (±1, 0) modes (Fig. 3).

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| **Fig. 2** Radial profile of each term in RHS of Eq. (8) at *t* = 1350. RHS1 indicates convective nonlinearity, RHS2, toroidal coupling, RHS5, dissipation, respectively. | **Fig. 3** Radial profile of each term in RHS of Eq.(9) at *t* = 1350.  |

**4 Summary**

The nonlinear simulation is performed using the 4-field RMHD model with particle source to investigate the nonlocal transport phenomena. It is found that the nonlocal transport appears in the vicinity of *q* = 3/2 surface after switching-off the source as a transient plasma response. In this simulation, *p*(r, ±1, 0) modes play an important role in the nonlocal transport.

 As future works, (1) the q-dependence (the role of rational surface), (2) the source shape such as 3D spherical source, (3) the cold pulse propagation taking electron temperature fluctuation into account should be investigated to identify the nonlocal transport.

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