P5.154 *Bifurcation Structure in Resistive Drift Wave Turbulence*

Ryusuke Numata, Rowena Ball, Robert L. Dewar

Department of Theoretical Physics, Research School of Physical Sciences and Engineering,
The Australian National University, Canberra ACT 0200, AUSTRALIA

ryusuke.numata@anu.edu.au http://wwwrsphysse.anu.edu.au/~num105/

In this work we report the results of numerical simulation of the modified Hasegawa-Wakatani model, which describes resistive drift wave turbulence in tokamak edge plasmas. The HW model is a simple model, but contains an interesting physics, i.e. turbulence-shear flow interaction. This simulation study also complements the low-dimensional modeling results which we already have.

Modified Hasegawa-Wakatani Model

MHW model describes evolution of density fluctuation n and vorticity $\zeta=\nabla^2\varphi$ (φ : electrostatic potential)

$$\frac{\partial\zeta}{\partial t}+[\varphi,\zeta] = \alpha(\tilde{\varphi}-\tilde{n})-D_\zeta\nabla^4\zeta$$

$$\frac{\partial n}{\partial t}+[\varphi,n] = \alpha(\tilde{\varphi}-\tilde{n})-\kappa\frac{\partial\varphi}{\partial y}-D_n\nabla^4 n$$

$[a,b]=\partial a/\partial x\,\partial b/\partial y-\partial a/\partial y\,\partial b/\partial x,\ \nabla^2=\partial^2/\partial x^2+\partial^2/\partial y^2$

D_ζ, D_n : dissipation coefficients (Prandtl number $P_r=D_\zeta/D_n$)

$$\kappa=\frac{-\partial}{\partial x}\ln n_0,\quad \alpha=\frac{T_e k_z^2}{\eta n_0 \omega_{ci} e^2}$$

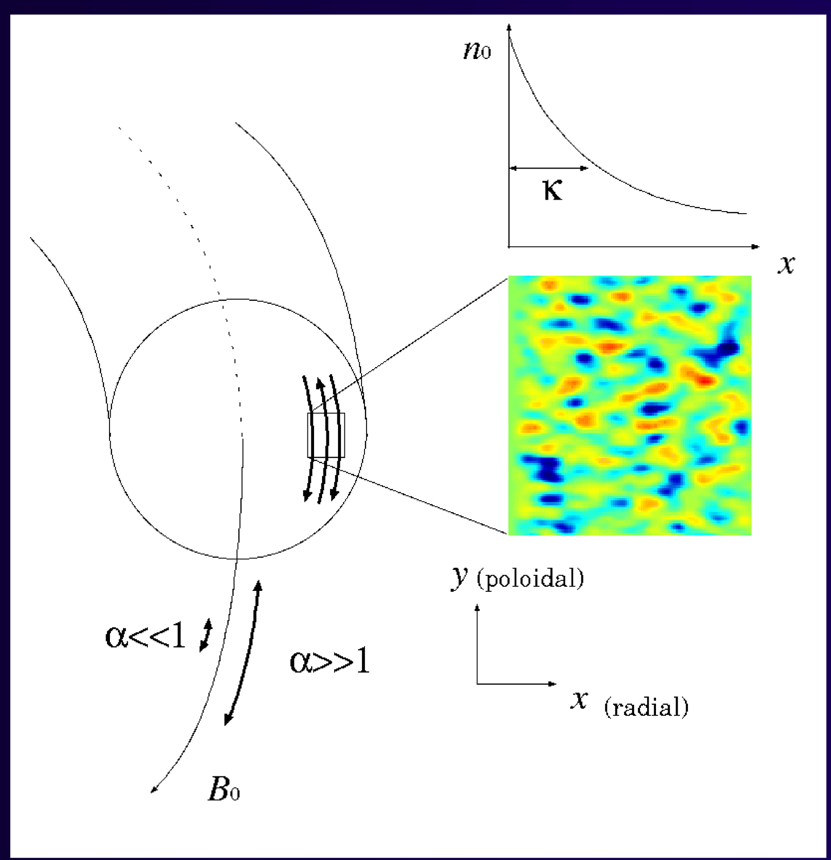
Resistive coupling term which comes from parallel electron response $\partial j_z/\partial z=1/\eta\,\partial^2(\varphi-n)/\partial z^2$ (Ohm's law)

does not act on the zonal components ($k_y=k_z=0$)

Original HW → MHW
$\alpha(\varphi-n)\rightarrow\alpha(\tilde{\varphi}-\tilde{n})$

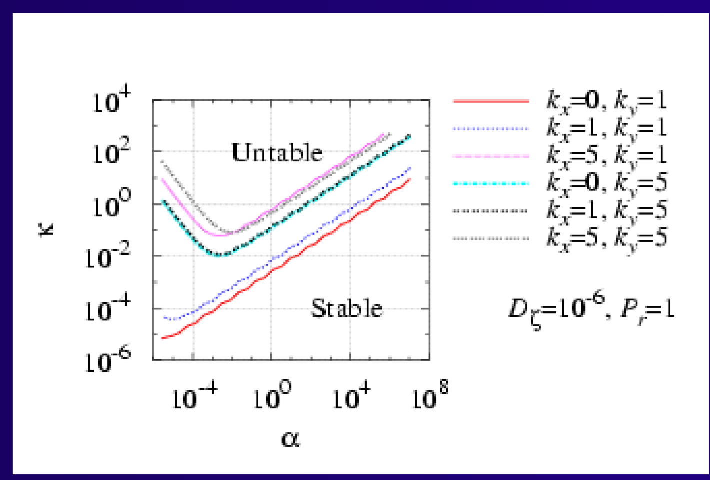
Zonal: $\langle f\rangle=\frac{1}{L_y}\int f\,dy$ (f stands for φ and n)

Non-zonal: $\tilde{\varphi}=\varphi-\langle\varphi\rangle,\ \tilde{n}=n-\langle n\rangle$



Stability Diagram Provides Indication of Transition Points

Stability threshold in α - κ space



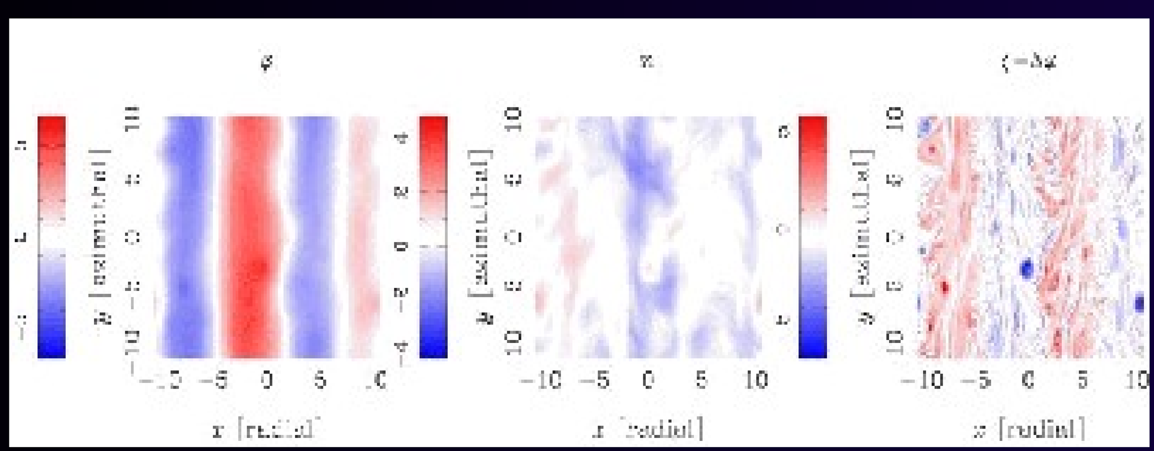
For finite α one positive growth rate if $D=0$ (dissipationless)
large $\kappa\rightarrow$ destabilizing, large $\alpha\rightarrow$ stabilizing

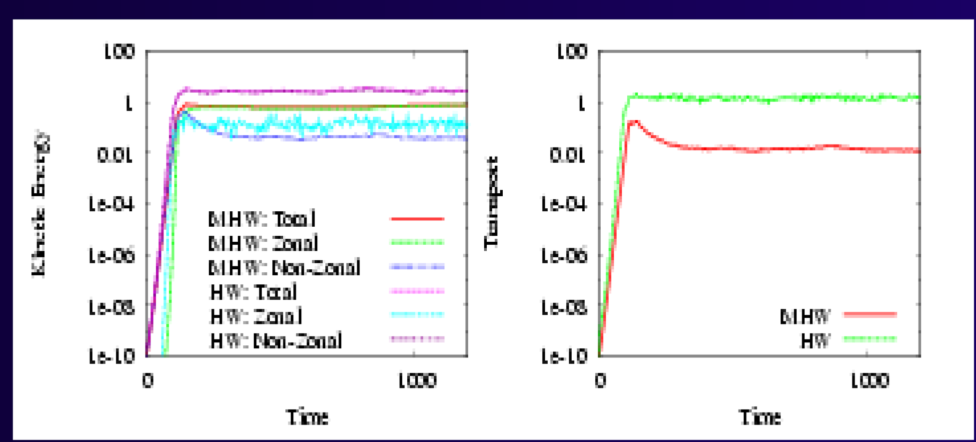
Numerical Algorithm to Solve MHW Model

- MHW model is solved in 2D slab geometry
- Box size L, determined by smallest wavenumber $\Delta k=0.3$ $[(2L)^2=(2\pi/\Delta k)^2]$
- Periodic boundary in both x and y direction
- Time stepping algorithm is a 3rd order explicit linear multistep method
- Finite difference method is used for spatial discretization
- Poisson bracket term evaluated by the Arakawa's method (Arakawa(1966))
- Implemented on APAC-NF SGI Altix 3700 Bx2 Cluster

Zonal Flow Generation and Transport Suppression

Contour plot of saturated variables for $\kappa=1, \alpha=1, D_\zeta=10^{-6}, P_r=1$



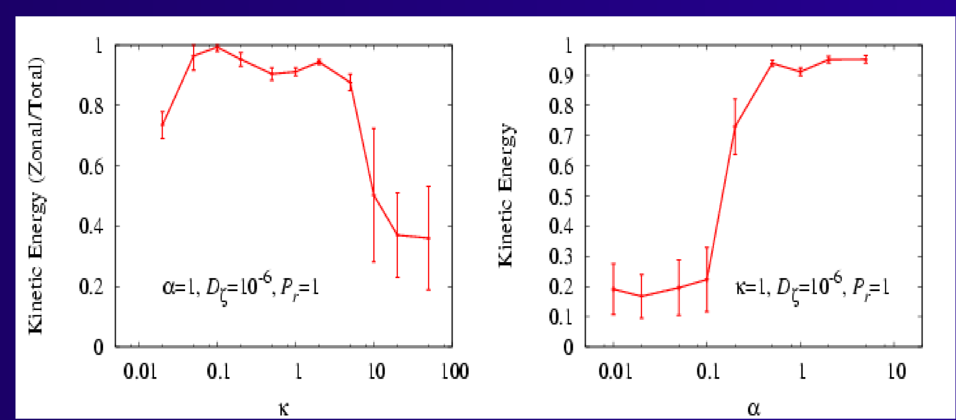


Kinetic energy $E=\frac{1}{2}\int|\nabla\varphi|^2\,dxdy$

Zonal kinetic energy $F=\frac{1}{2}\int\left(\frac{\partial\langle\varphi\rangle}{\partial y}\right)^2 dx\,dy$

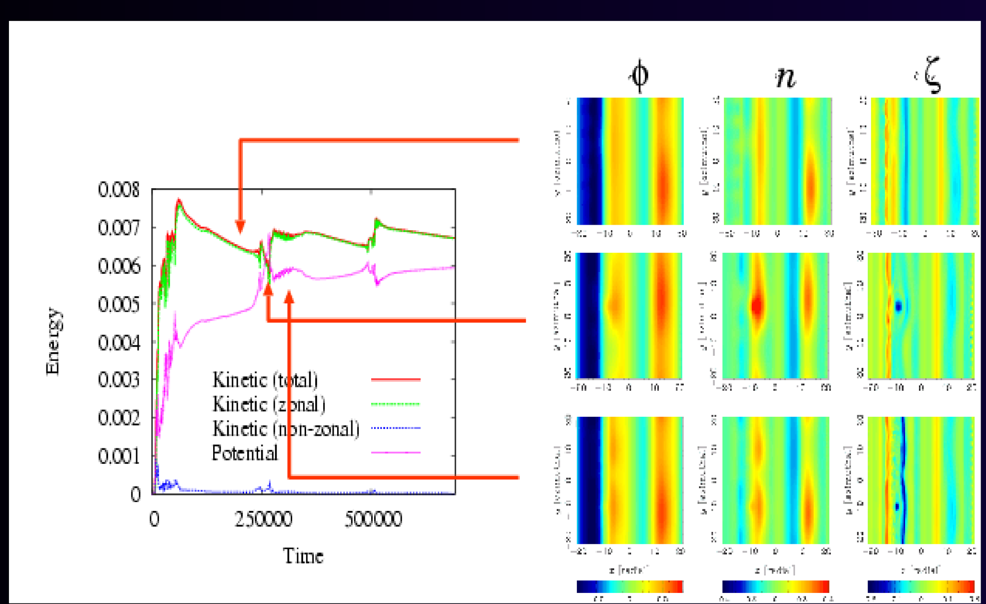
Cross-field transport $\Gamma_n=-\kappa\int n\,\partial\varphi/\partial y\,dxdy$

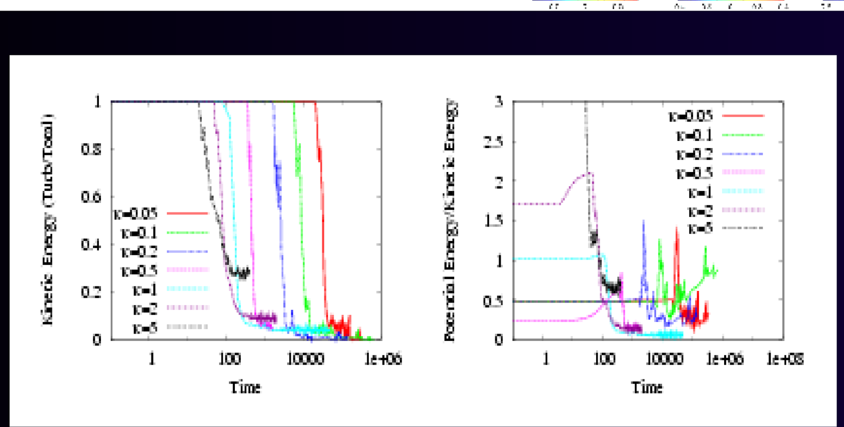
Transition to Zonal Flow Suppressed Regime



Sudden transition occurs if we move parameters to linearly more unstable direction

Relaxation Oscillation Observed for Weak Drive Case ($\kappa=0.1$)



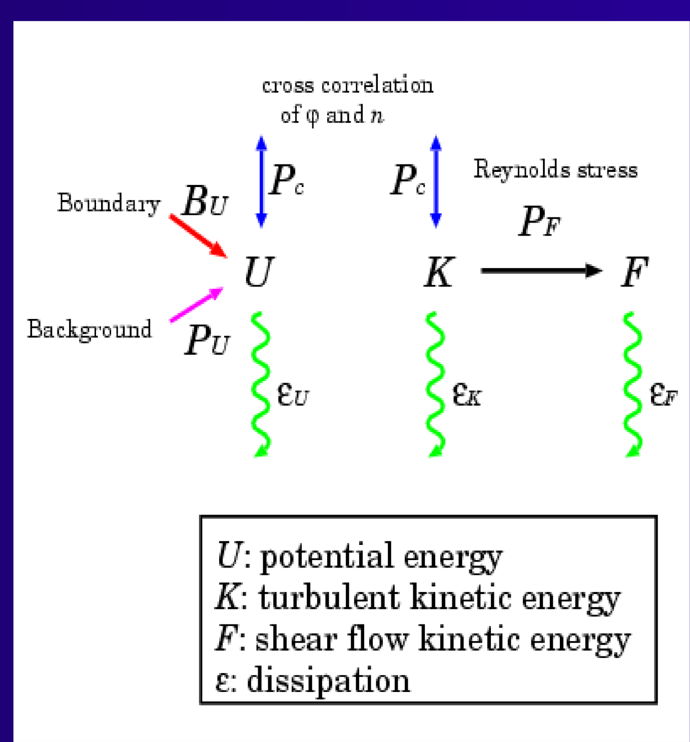


- Instability → Energy exchange between kinetic and potential energy
  → Resistive dissipation (parallel motion) [relatively large adiabaticity]
- Turbulent kinetic energy << Zonal kinetic energy
- Competition between zonal kinetic energy and potential energy

Summary and Conclusion

- We have performed simulations of modified Hasegawa-Wakatani model
- Zonal flows are generated, and the zonal flows suppress cross-field turbulent transport in MHW model
- Transition from zonal flow dominant to zonal flow suppressed state is observed
- Bifurcation points correspond to linear stability boundary
  (Does this correspond to the Dimits shift?)
- Long time simulation shows relaxation oscillation type behavior in low κ (weak drive) case
- For low κ case, potential energy is comparable to zonal kinetic energy, and turbulent kinetic energy is much smaller
- Equations describing time evolution of energies are derived to consider energetics in MHW model
- Corresponence of bifurcation diagram obtained from numerical simulation and from low-dimensional model should be considered

Energetics of MHW Model



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