Alfvén mode and zonal structure generation

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XHMGC Model

- The evolution of the poloidal magnetic flux function:

$$\frac{\partial \psi}{\partial t} = -\frac{cR^2}{R_0 B_0}\nabla\psi \times \nabla\varphi \cdot \nabla\phi - \frac{c}{R_0}\frac{\partial \phi}{\partial \varphi} + \eta\frac{c^2}{4\pi}\Delta^*\psi + O(\epsilon^4 v_A B_\varphi) \quad (1)$$

- The evolution of the scalar potential:

$$\hat{\rho}\left(\frac{D}{Dt} - \frac{2c}{R_0 B_0}\frac{\partial \phi}{\partial Z}\right)\nabla_\perp^2\phi + \nabla\hat{\rho}\cdot\left(\frac{D}{Dt} - \frac{c}{R_0 B_0}\frac{\partial \phi}{\partial Z}\right)\nabla\phi = \quad (2)$$

$$-\frac{B_0}{4\pi}\mathbf{B}\cdot\nabla\Delta^*\psi - \frac{B_0}{cR_0}\nabla\cdot\left(R^2(\nabla\cdot\Pi_i + \nabla\cdot\Pi_H)\times\nabla\varphi\right)$$

$$+O\left(\epsilon^4\rho\frac{v_A^2 B_\varphi}{a^2 c}\right)$$

XHMGC Model

- The evolution of the poloidal magnetic flux function:

$$\frac{\partial \psi}{\partial t} = -\frac{cR^2}{R_0 B_0}\nabla\psi \times \nabla\varphi \cdot \nabla\phi - \frac{c}{R_0}\frac{\partial \phi}{\partial \varphi} + \eta\frac{c^2}{4\pi}\Delta^*\psi + O(\epsilon^4 v_A B_\varphi) \quad (3)$$

- The evolution of the scalar potential:

$$\hat{\rho}\left(\frac{D}{Dt} - \frac{2c}{R_0 B_0}\frac{\partial \phi}{\partial Z}\right)\nabla_\perp^2 \phi + \nabla\hat{\rho} \cdot \left(\frac{D}{Dt} - \frac{c}{R_0 B_0}\frac{\partial \phi}{\partial Z}\right)\nabla\phi = \quad (4)$$
$$-\frac{B_0}{4\pi}\mathbf{B} \cdot \nabla\Delta^*\psi - \frac{B_0}{cR_0}\nabla \cdot (R^2(\nabla \cdot \Pi_i + \nabla \cdot \Pi_H) \times \nabla\varphi)$$
$$+O(\epsilon^4 \rho \frac{v_A^2 B_\varphi}{a^2 c})$$

- Electrostatic simulation

EQUILIBRIUM AND INITIALIZATION

- The q profile is $q(r/a) = q_0 + 0.05 * (r/a)^2$, $a/R = 0.1$. In our simulations, $q_0 = [1.2, 1.4, 1.6, 2.0, 2.5]$, $V_{th}/V_A = [0.04, 0.06, 0.08]$ and $\rho/a = [0.003125, 0.0046875, 0.00625]$ cases are simulated.
- The initial perturbation is shown here:

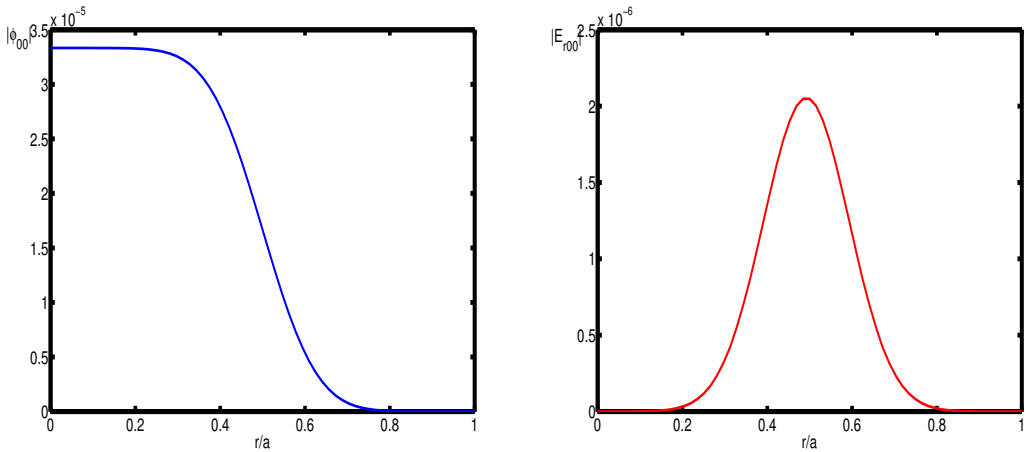

Figure: (a) is the initial perturbation of ϕ_{r00} and (b) is the corresponding E_{r00}.

SIMULATION RESULTS

The time evolution of E_{r00} at radial position of $r/a \sim 0.5$, for $q_0 = 1.6$ and $V_{th}/V_A = 0.08$ as an example, is shown here:

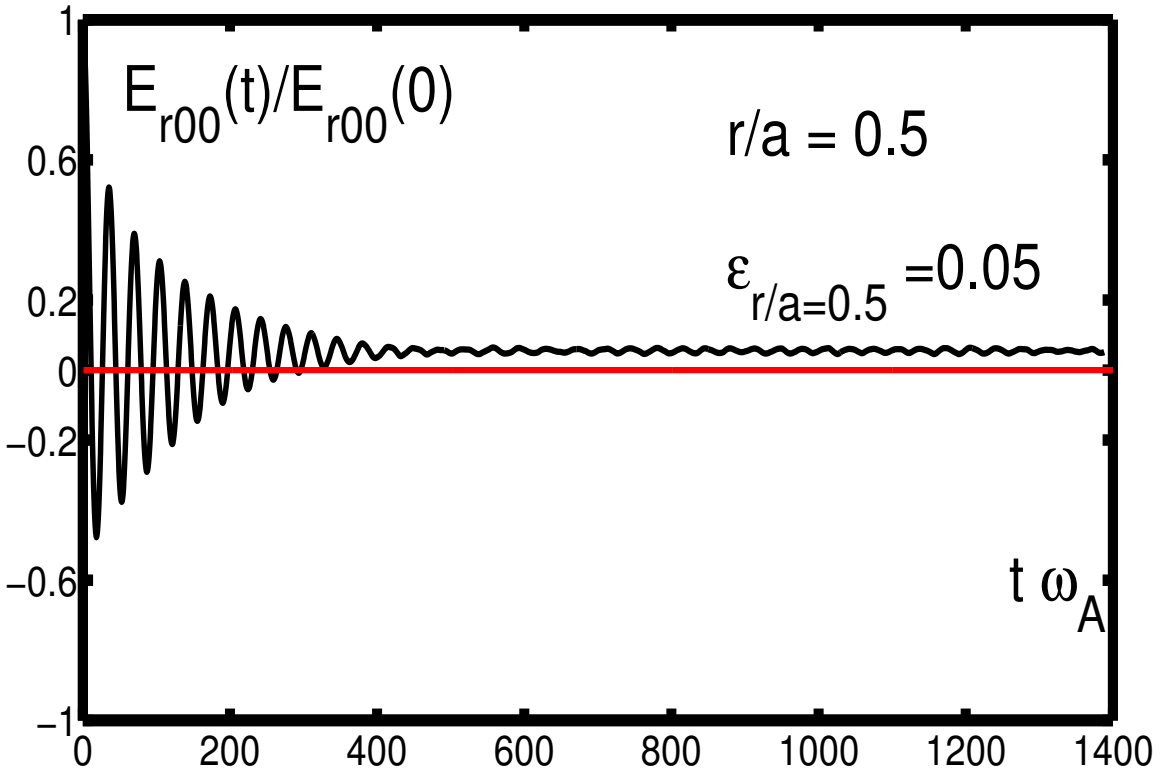

Figure: Time evolution of E_{r00} at $r/a \sim 0.5$, for $q = 1.6$ case.

REAL FREQUENCIES

The following parameter scan simulations are following the results in [A. Biancalani et al Nucl. Fusion 54 (2014) 104004].

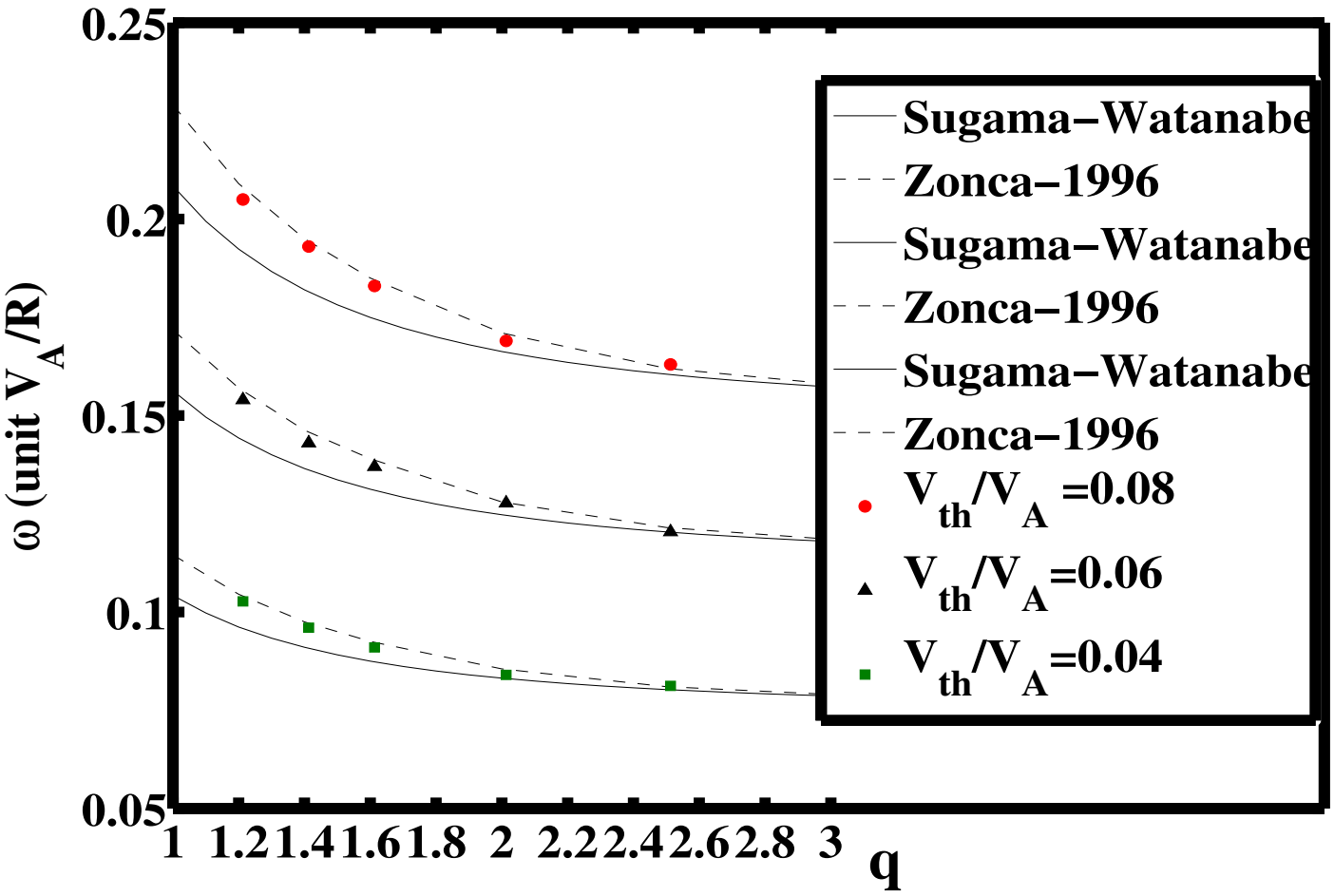

Figure: Real frequencies

Damping rates

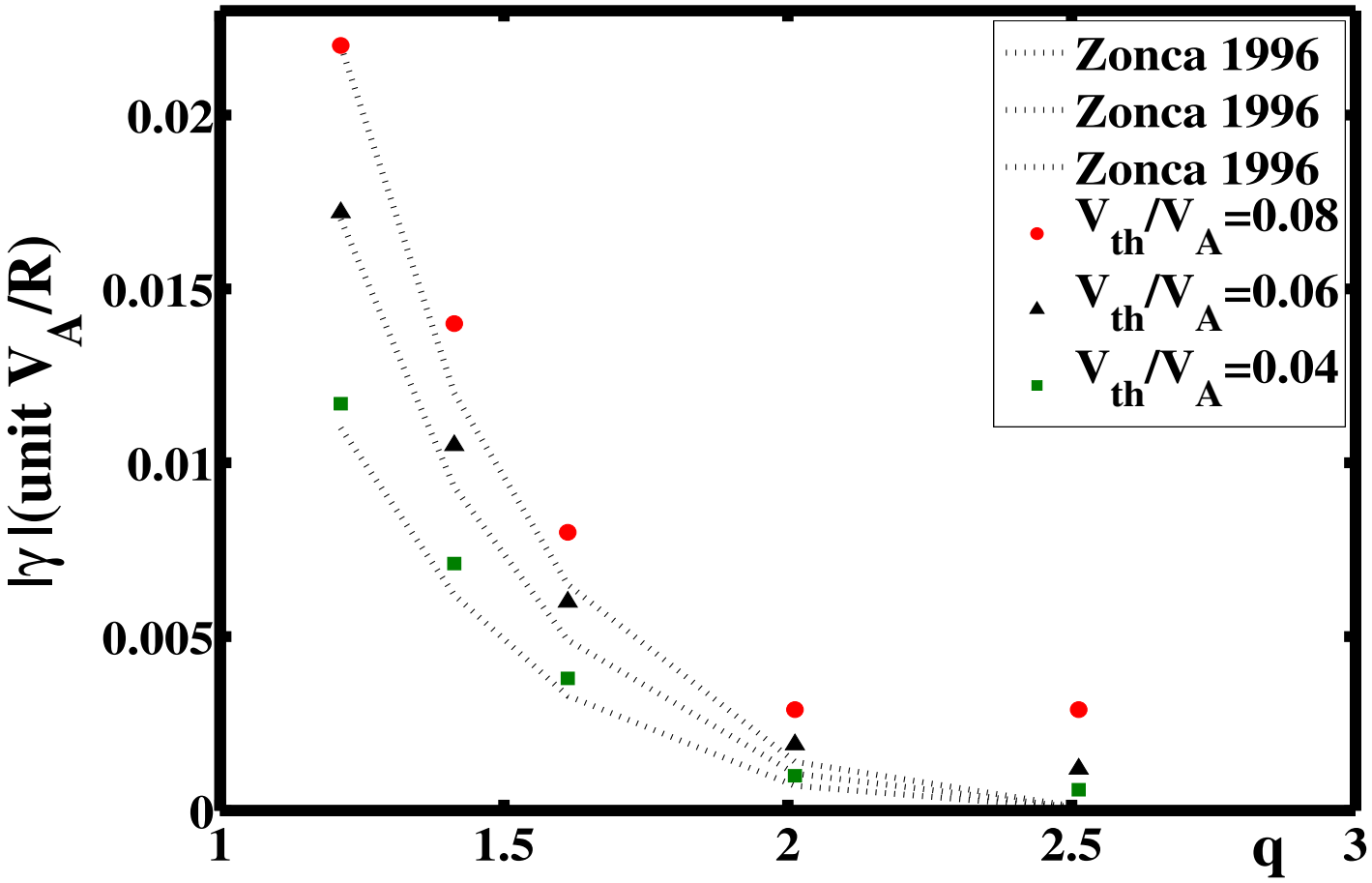

Figure: Damping rate.

RESIDUAL LEVEL

The residual level is shown here.

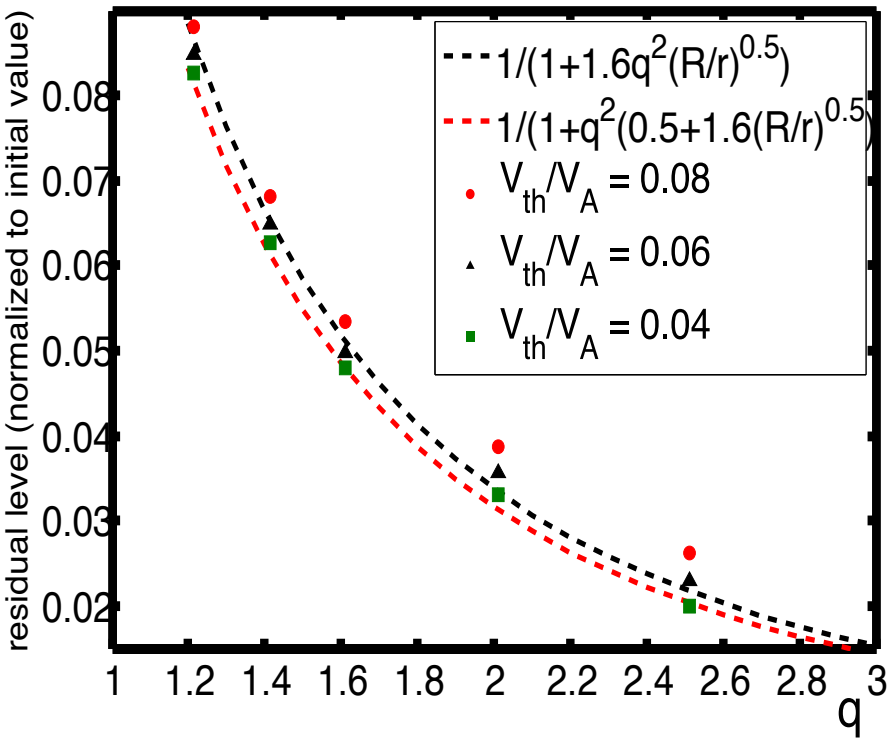

Figure: Residual level.

Next step

- Repeat the above simulations using the full set equations of XHMGC.
- In the paper [Todo, Berk and Breizman Nucl. Fusion 50 (2010) 084016], it is shown the zonal flow is forced driven by unstable TAE mode and the growth rate is $2\gamma_{TAE}$.