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Introduction&Background

粒子和热量的径向输运：实验 > 新经典理论

新经典理论:

- 碰撞扩散 –> 输运 (minimal)
- 不稳定性 (ITG, TEM; ETG, TIM): 小尺度, 低频 (ω_{ci}) –> 微湍流 –> 带状流
- 带状流
  - 减小湍流输运
  - ITG 湍流的阈值增加

带状流阻尼模拟

- 残留: Gyrokinetic $>$ Gyrofluid
- Gyrokinetic 轴对称的带状流，不能被线性无碰撞阻尼掉 -> Gyrofluid 的阻尼项不合适
- R-H: 残留带状流反比于等离子体径向的极化 <– (磁漂移,bounce motion $>$ 回旋运动)
    - 无碰撞: 极化主要是捕获和通行离子偏离流表面
    - 有碰撞:
        - driving frequency $<< \nu_{ii}$;
        - $\nu_{ii} <<$ driving frequency
- 新经典极化 $>$ 经典极化: $\frac{B_T^2}{B_p^2}$

计算新经典极化 (H-R)

- drift kinetic equation

Neoclassical Polarization

R-H collisionless polarization

$$\varepsilon_k^{pol}(p) = \frac{\omega_{pi}^2}{\omega_{ci}^2}(1 + 1.6\frac{q^2}{\sqrt{\epsilon}})$$

R-H collisional polarization

- high frequency,low collisionality ($p\tau_{ii} \gg 1$)

$$\varepsilon_{k,nc}^{pol}(p) = \frac{\omega_{pi}^2}{\omega_{ci}^2}\frac{q^2}{\sqrt{\epsilon}}(1.6 + \frac{3\sqrt{2}\pi}{\gamma\Lambda}), \text{ where } \gamma\Lambda \gg 1$$

- low frequency, collisional ($p\tau_{ii} \ll 1$)

$$\varepsilon_{k,nc}^{pol}(p) = \frac{\omega_{pi}^2}{\omega_{ci}^2}\frac{q^2}{\epsilon^2}[1 - \frac{8p\tau_{ii}}{\sqrt{\pi}}(1 - 1.461\sqrt{\epsilon})]$$

Collisional Neoclassical Polarization

$$\varepsilon_{k,nc}^{pol}(p) = \frac{\omega_{pi}^2}{\omega_{ci}^2}\frac{q^2}{\epsilon^2}(1 - P_1)$$

$$P_1 = \frac{3}{2}\int_0^{1-\epsilon} d\lambda \langle G_k \rangle_E ==> P_1 = (1 - 1.6\epsilon^{3/2})\frac{\gamma_0}{\gamma_0 + \frac{\sqrt{\pi}}{8}\mu_1}$$

$$\varepsilon_{k,nc}^{pol}(p) = \frac{\omega_{pi}^2}{\omega_{ci}^2}\frac{q^2}{\epsilon^2}\frac{1.6\epsilon^{3/2} + \frac{\sqrt{\pi}}{8}\mu_1}{\gamma_0 + \frac{\sqrt{\pi}}{8}\mu_1}$$, where $\gamma_0 = p\tau_{ii}$, and $\mu_1 = 1 + 1.46\sqrt{\epsilon}$

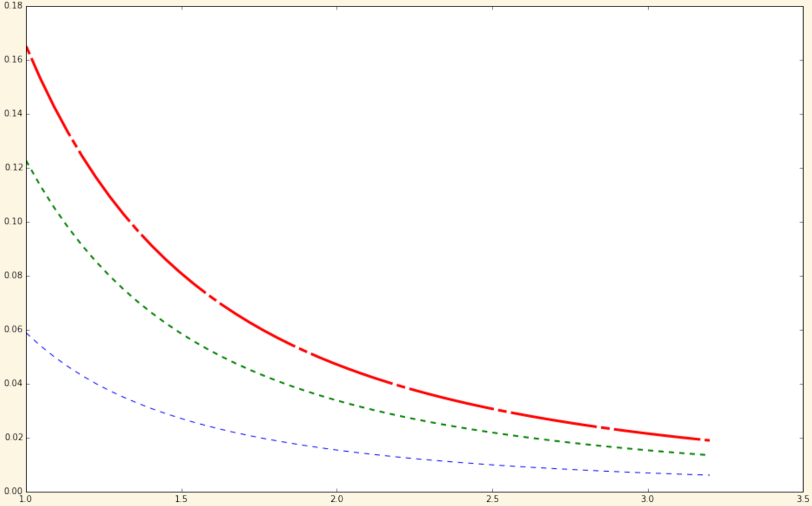
Zonal Flow Damping

$$\phi_k(t) = A_1 \exp^{-\gamma t} \cos(\omega t + \alpha) + A_2$$

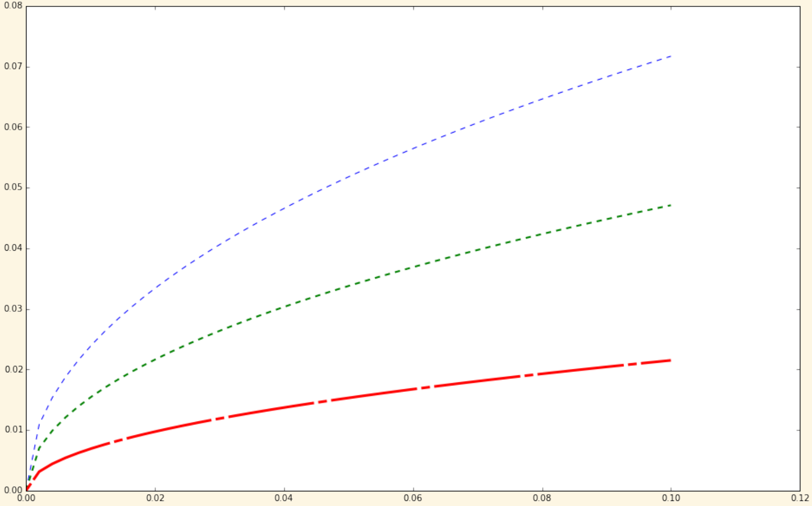
Zonal Flow Potential (R-H collisionless polarization)

$$\frac{\phi_k(t=\infty)}{\phi_k(t=0)} = \frac{\varepsilon^{pol}_{k,cl}(p)}{\varepsilon^{pol}_{k,cl}(p)+\varepsilon^{pol}_{k,nc}(p)} = \frac{1}{1+1.6*q^2/\sqrt{\epsilon}}$$

```
import numpy as np
import matplotlib.pyplot as plt
figsize(16,10)

q = np.linspace(1.0, 3.2)
epsl=0.01
line, = plt.plot(q, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', line
epsl=0.05
line, = plt.plot(q, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', line
epsl=0.1
line, = plt.plot(q, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', line

dashes = [10, 5, 100, 5] # 10 points on, 5 off, 100 on, 5 
line.set_dashes(dashes)

plt.show()
## r/R =0.01,0.05,0.1, residual level with q(r)
```


0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1.0
1.5
2.0
2.5
3.0
3.5

```
epsl = np.linspace(0.0, 0.1)
q=1.6
line, = plt.plot(epsl, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', l
q=2.0
line, = plt.plot(epsl, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', l
q=3.0
line, = plt.plot(epsl, 1/(1+1.6*q*q/np.sqrt(epsl)), '--', l

dashes = [10, 5, 100, 5] # 10 points on, 5 off, 100 on, 5 o
line.set_dashes(dashes)

plt.show()
## q(r) =1.6,2.0,3.0, residual level with r/R
```



0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12

Today's date is January 15, 2015.