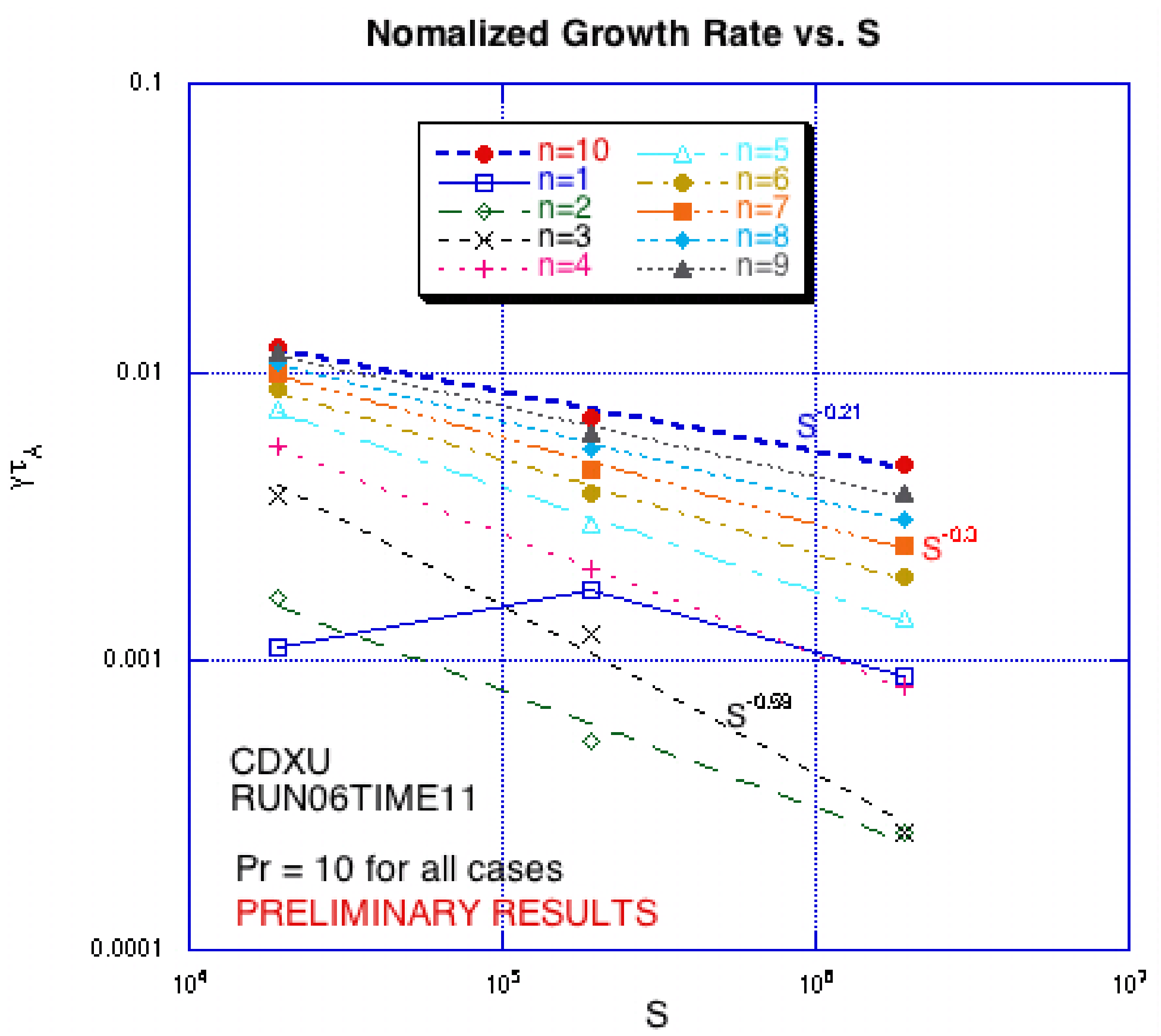
Resistive Ballooning Modes in CDX-U

H. Strauss

Resistive Ballooning Modes: physical or numerical?

- **Resistive ballooning modes tend to be present in finite beta resistive MHD numerical simulations – CDX-U**
- **Are they important in experiments?**
  - **Edge turbulence**
- **What physics stabilizes them?**
- **Complicating issue: simulations are usually much more resistive than simulations**
  - **CDXU an exeption, S is the same in exp. and simulations**
- **Most theory done 20 years ago**

CDX-U simulations



RBM Electromagnetic (long wavelength) limit

- **Validity condition: m = nq < 10**

$$\gamma >> \eta m^2 / r^2$$

- **Dispersion relation in electromagnetic limit is like tearing mode (Chance, Drake, Glasser, Strauss…)**

$$\gamma = \gamma_t = (\eta m^2 / r^2)^{3/5} \Delta^{4/5} \tau_A^{-2/5}$$

- **Interchange coupling is important at moderately high S**

$$\Delta = \Delta(\beta q^2 R / r)$$

  - **Tokamaks: stabilizing**
    - **If not too close to ideal instability boundary**
  - **Stellarators: destabilizing**
- **2 fluid drifts**
  - **Validity condition**
  - **Stabilizing, growth rate negligible**

$$\omega_* > \gamma_t$$

$$\omega(\omega - \omega_{*i})(\omega - \omega_{*e})^3 = \gamma_t^5$$

RBM Electrostatic (short wavelength) limit

- **Validity: m >> 10**
- **Carreras – Diamond, …**
- **Can be stabilized by sound waves (Hender)**
  - **Not valid for very large m**
- **2 fluid**
  - **Validity condition**
  - **Drift stabilizes modes**
  - **Growth rate proportional to resistivity, independent of m**
  - **If temperature gradient length is sufficiently shorter than density gradient length, modes are completely stable**

$$\gamma << \eta m^2 / r^2$$

$$\gamma_{es} = (\eta m^2 / r^2)^{1/3} \Delta^{2/3} \tau_A^{-2/3}$$

$$\Delta = \beta q^2 R / r$$

$$\gamma << c_s / qR$$

$$\omega_* > \gamma_{es}$$

$$\omega(\omega - \omega_{*i})(\omega - \omega_{*e}) = \gamma_{es}^3$$

CDX-U electrostatic modes- can they be stabilized?

- **Hall parameter H = .15, beta =.03,S = 10^4, q=3**
- **Drift condition can't be satisfied, m < 1000, sensitive to H.**
- **Sound wave only stabilizing with large enhancement but not for all m.**
- **CDX-U RBM turbulent**
- **Perpendicular thermal conduction can help stabilize RBMs.**

$$H = c/(\omega_{pi} R)$$

$$\omega_* \tau_A = mH\beta R^2 / r^2$$

$$\omega_* > \gamma_{es}$$

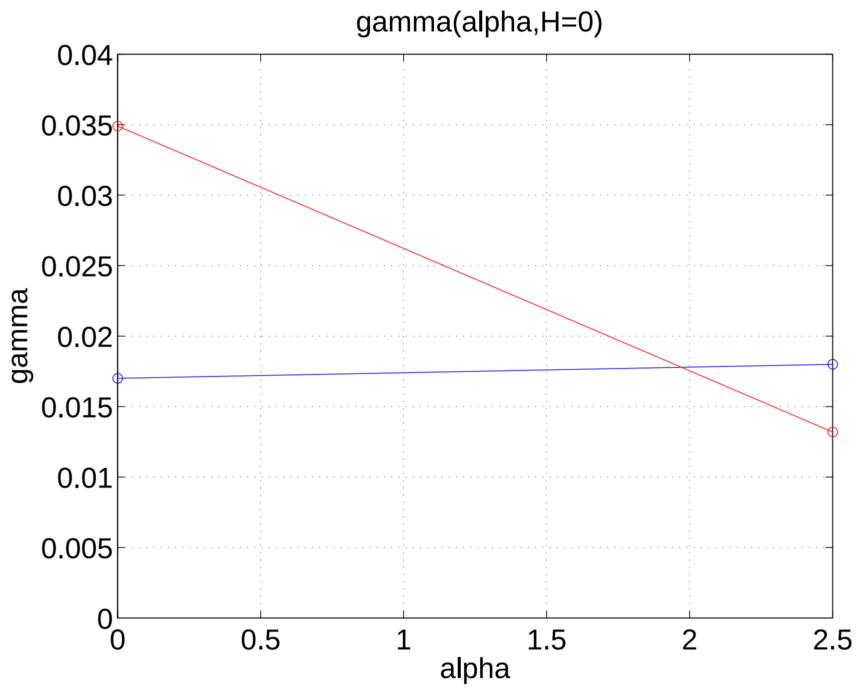
$$m\ H^3 \beta\ \ > S^{-1}(qr/R)^4$$

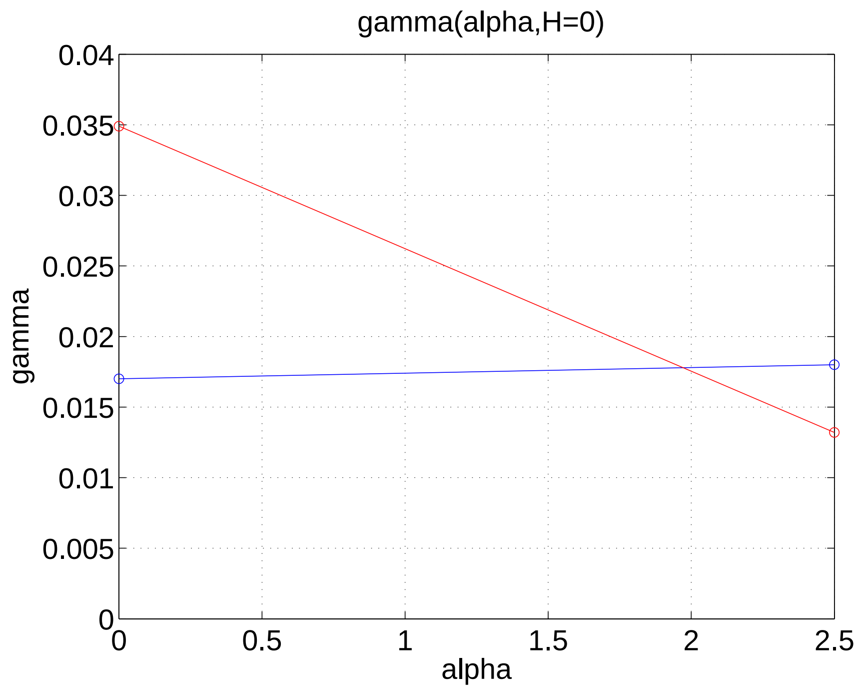
$$\alpha c_s / qR > \gamma_{es}$$

$$\alpha > S^{-1/3} m^{2/3} \beta^{1/6} q^{7/3}$$

2 Fluid and enhanced sound effects
n=1, 4

H has almost no effect





Sound speed has large enhancement $\alpha = 2.5 \frac{v_A}{c_s} \approx 25$

Conclusions

- **Resistive MHD**
  - **Long wavelength**
    - **stabilized by interchange coupling in tokamaks, for S > 10^5**
  - **Short wavelength**
    - **Stabilized by sound, for moderate m.**
    - **Large m is unstable**
- **2 fluid drifts**
  - **Validity condition is harder to satisfy in simulations than in experiments because S is smaller – except in CDX-U**
  - **Stabilizes or greatly slows down RBMs**
- **CDX-U is RBM unstable, nonlinearly turbulent**
  - **Can be stabilized with artificial H or sound speed or cross field thermal conduction.**