Stabilizing impact of β' on microturbulence

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Outline

$\beta' = d\beta/d\rho$, with $\rho \sim r/a$

- Presentation of the gyrokinetic code used
- Theoretical explanation of the stabilizing β' impact
- Relevance to high β NSTX plasmas

Tool for microstability analysis

- linear gyrokinetic electromagnetic code
  - Vlasov equation to link δf to $\delta\phi, \delta B_{//}, \delta B_{\perp}$
  - Maxwell equations to constrain δf vs. $\delta\phi, \delta B_{//}, \delta B_{\perp}$

→ From a given $k_\theta \rho_i$ and a given set of n, T, q, ∇n, ∇T, s gives ω of unstable modes with $\gamma = \mathrm{Im}(\omega)$

Code used here: GS2 provided by W. Dorland

M. Kotschenreuther, et al, Comp. Phys. Com. **88** (95)

Theoretical reason for β' stabilization

- In a similar way of low and negative magnetic shear, high |β'| leads to lower ∇B and curvature drift, therefore lower interchange instability

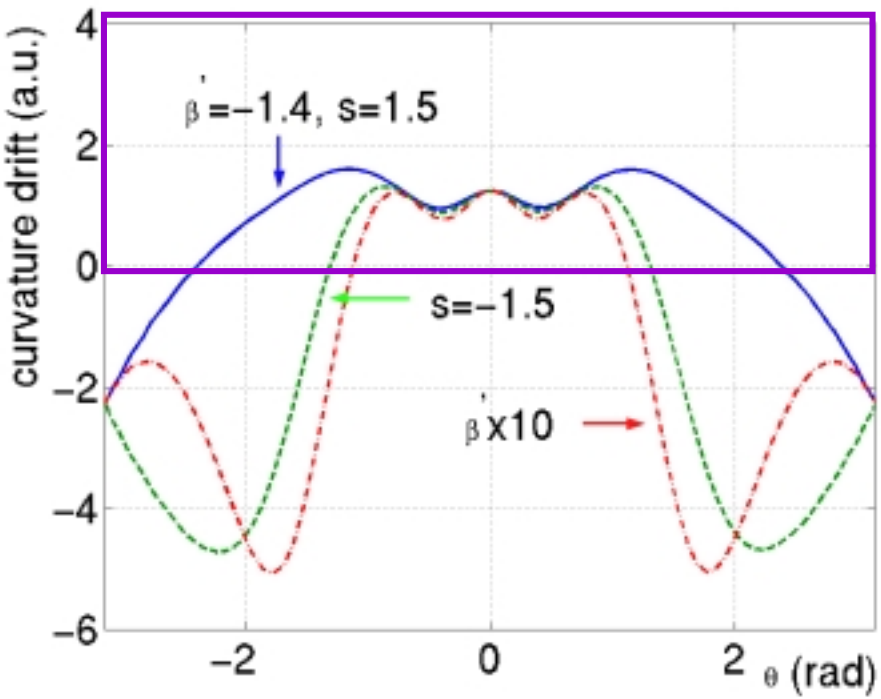
- In a 's-α' analytic equilibrium where $\alpha = - q^2 R\beta'$

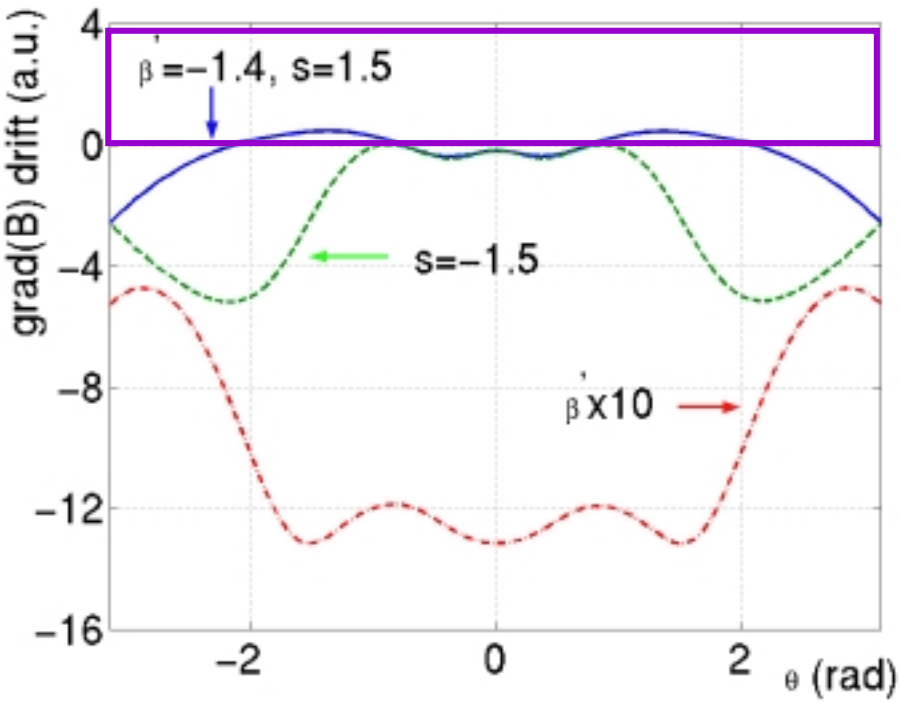
  $\omega_{\nabla B} = \omega_K \propto \cos\theta + (s\theta - \alpha \sin\theta)\sin\theta$

- In a general equilibrium at high β, $\omega_K = \omega_{\nabla B} + \mathbf{b}\times\nabla\beta$
  therefore stabilizing |β'| impact expected to be enhanced, but $\delta B_{//}$ effect cancels this impact

Similar stabilizing impact of β' and s on curvature and ∇B drifts

- Higher |β'|, as low or negative s = lower curvature and ∇B drifts = lower interchange instability





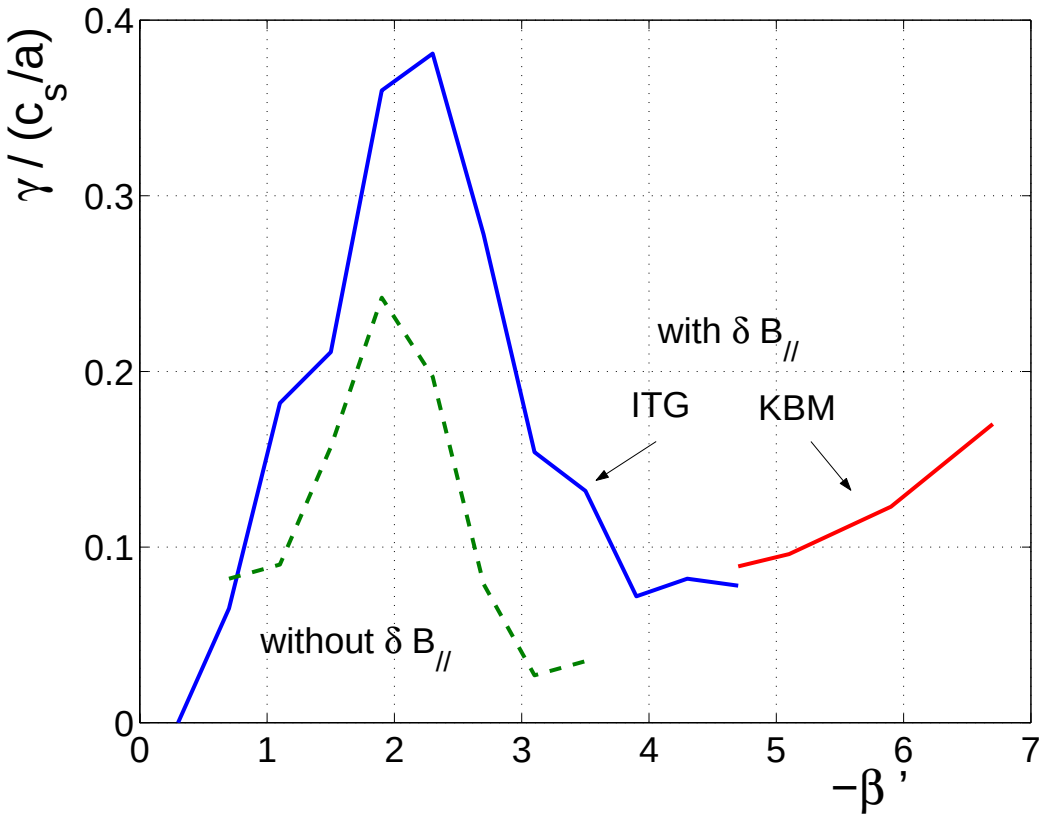
Drifts from computed magnetic equilibrium

ITG stabilized by high |β'| despite higher |∇P / P|

- β' scan at fixed β and η, β = 20%, η_i = 3
- adiabatic electrons

- $k_\theta \rho_i$ ~ 0.4 for ITG
- $k_\theta \rho_i$ ~ 0.15 for KBM

- Neglecting $\delta B_{//}$ effects:
  - underestimation of γ
  - overestimation of stabilizing |β'| impact



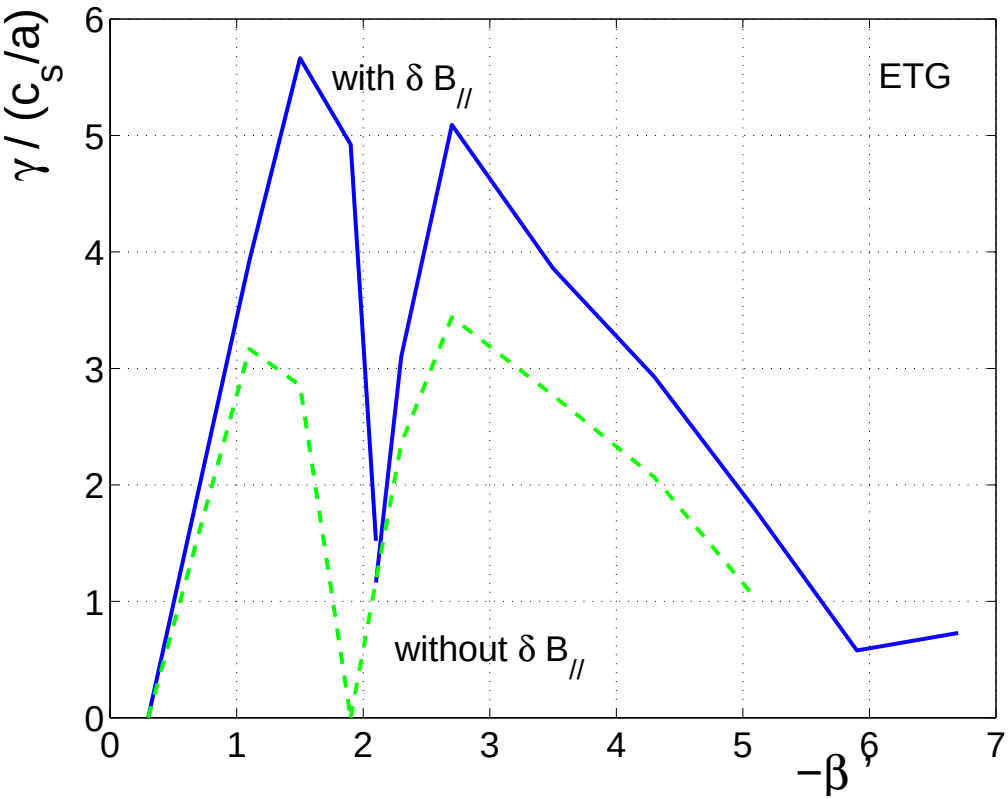
computed equilibrium NSTX #106382 at 0.21 s and r/a=0.4, s=1.3, real β' = -1.1

TEM and ETG stabilized by high |β'| despite higher |∇P / P|

- β' scan at fixed β and η, β = 20%, η_e = 3
- adiabatic ions

- $k_\theta \rho_e$ ~ 0.3 for TEM
- $k_\theta \rho_e$ ~ 0.6 for ETG

- For correct high β ion and electron modes computation cannot neglect $\delta B_{//}$

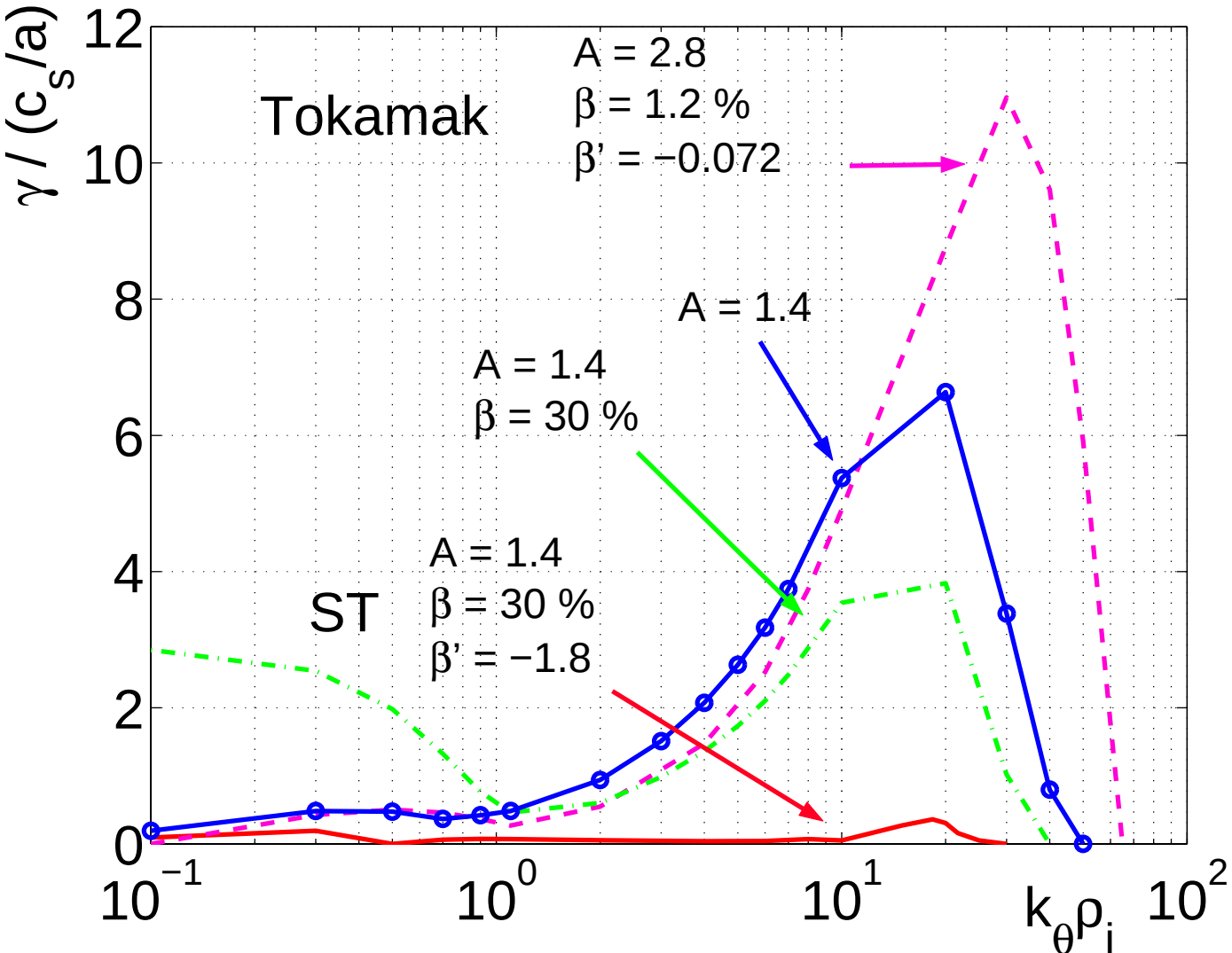


computed equilibrium NSTX #106382 at 0.21 s and r/a=0.4, s=1.3, real β' = -1.1

Higher |β'| explains lower growth rates in ST rather than low A and/or high β

Analytic Miller eq.

r/a = 0.5
$T_e = T_i = 1.5$ keV
$n_e = n_i = 2.10^{19}$ m^{-3}
shift = - 0.25
a.∇T/T = 4
a.∇n/n = 2
s = 1.5
q =1.5
κ = 1.5
κ' = 0.25
δ = 0.1
δ' = 0.08



Conclusions

- High $|\beta'|$ stabilize interchange instability
- Need to include $\delta B_{//}$ effects in high β plasma to avoid underestimation of growth rates
- Possibility of entering positive feedback loop in high β ST plasmas, either by maintaining more easily $\gamma < \gamma_E$ or thanks to β' alone when strong enough to compensate destabilizing higher $|\nabla P / P|$ to be explored experimentally. Should be easier with s low or negative and/or with low η, i.e. higher $\nabla n/n$ (pellet injection?)
- β' might be one of the player for ITB formation in standard tokamaks