# SBS in Multiple-Species Plasmas

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Summary

# We developed a model to study fast- and slow-wave SBS and how nonlinearities affect them

- Fast-wave SBS reflectivities are
  - significantly reduced by nonlinear saturation for $T_e/T_i \gtrsim 10$
  - not affected by nonlinear saturation for $T_e/T_i \lesssim 5$
- In CH plasmas, slow-wave SBS reflectivity is much lower than fast-wave SBS reflectivity.
- Slow-wave SBS reflectivities are significantly increased by nonlinear effects, but remain much smaller than fast-wave SBS.

# Outline

- Description of the model
- Fast-wave SBS at low and high ion temperatures
- Slow-wave SBS
- Conclusions

# We modeled SBS in CH plasmas at OMEGA-like parameters

- We modeled backscattering using a one-dimensional fluid model with phenomenological Landau-damping terms.
- Light wavelength: 0.35 $\mu$m
- Pump intensity: $I = 2.45 \times 10^{15} \frac{W}{cm^2}$
- Electron density: $n_e/n_{cr} = 0.46$
- Electron temperature: $T_e = 1$ keV

# Model consists of electron density, ponderomotive potential, ion-fluid equations, and Poisson equations

- **Electron density:** $n_e = \exp(\varphi) - P = 1 + \delta n_e$
- **Pondermotive potential:** $\partial_x P = \alpha \Im\left(n_{e_1}\right)\sqrt{P^2 + C^2}$,

  $\alpha = (\nu_e/c)^2 / ks, \;\; C = |a_0|^2 + |a_1|^2$

- **Ion-fluid equations for species "s":**

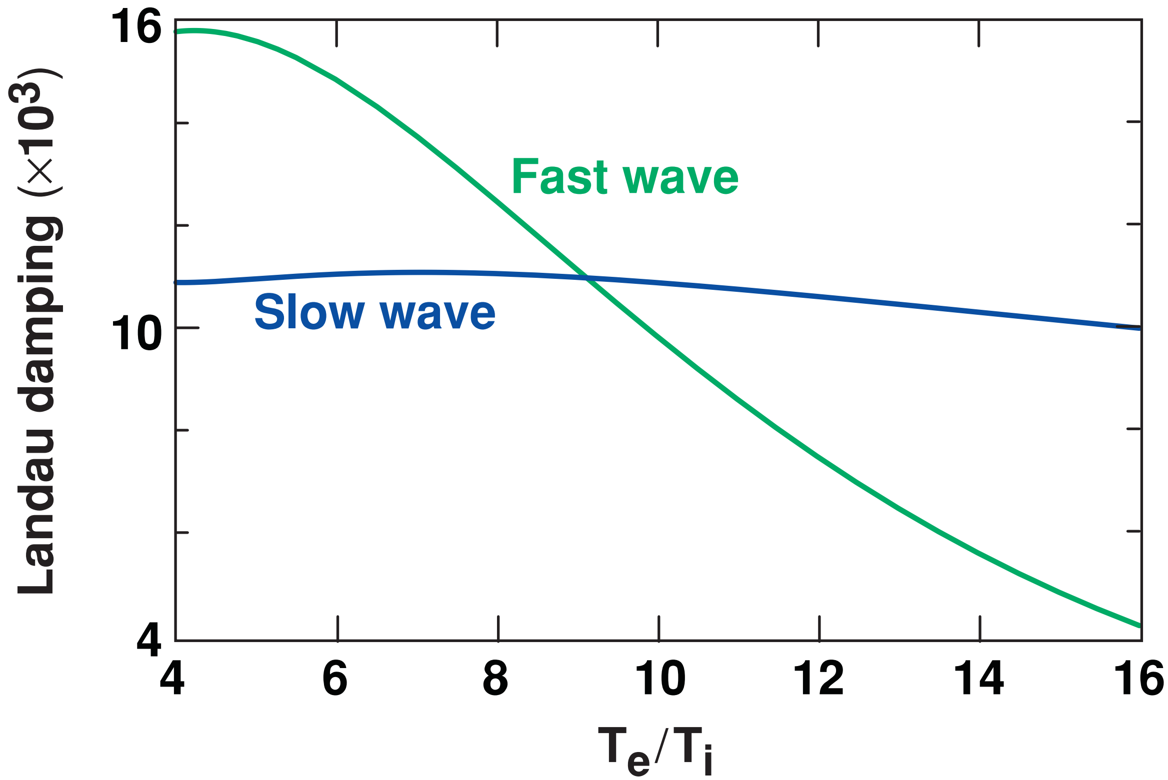
  $$\partial_t n_s + \partial_x (n_s u_s) + \lambda n_s = 0$$

  $$\partial_t u_s + u_s \partial_x u_s + \beta_s \partial_x \varphi + \gamma_s v_{ths}^2 n_s^{(\gamma_s - 2)} \partial_x n_s + \lambda u_s = 0$$

- $\lambda$–Landau damping coefficients; $\gamma_s$–polytropic indeces; $\beta_s = \dfrac{z_s M_r}{z_r M_s}$
- **Poisson equation:** $\partial_{xx}^2 \varphi - n_e + \sum_{s=\ell,h} \alpha_s n_s = 0; \quad \alpha_s = Z_s n_{0_s} / n_{0_e}$

# Results of kinetic model[1] are used to close the system of fluid Equations

- $\gamma = 3$ gives best agreement between fluid and kinetic phase velocities.
- Phenomenological damping terms correspond to imaginary parts of kinetic frequencies.

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[1]E. A. Williams *et al.*, Phys. Plasmas 2, 129 (1995).

# Damping of fast wave increases with ion temperature

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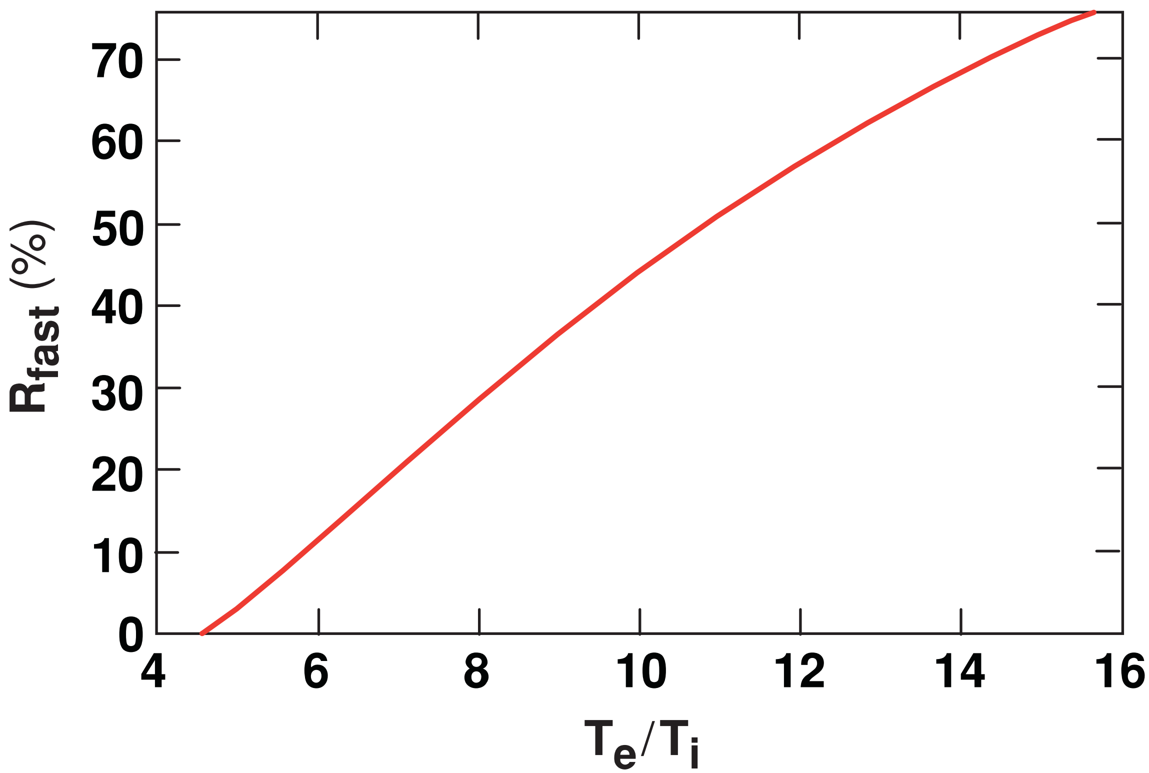
- Due to exponential dependence on damping, fast-wave SBS reflectivity decreases fast with increasing ion temperature.
- For $T_e/T_i = 5$, $\gamma/\omega_{pi} = 1.56 \times 10^{-2}$, $R_{fast} = 3\%$ → IA wave amplitude is small → nonlinearities are weak.

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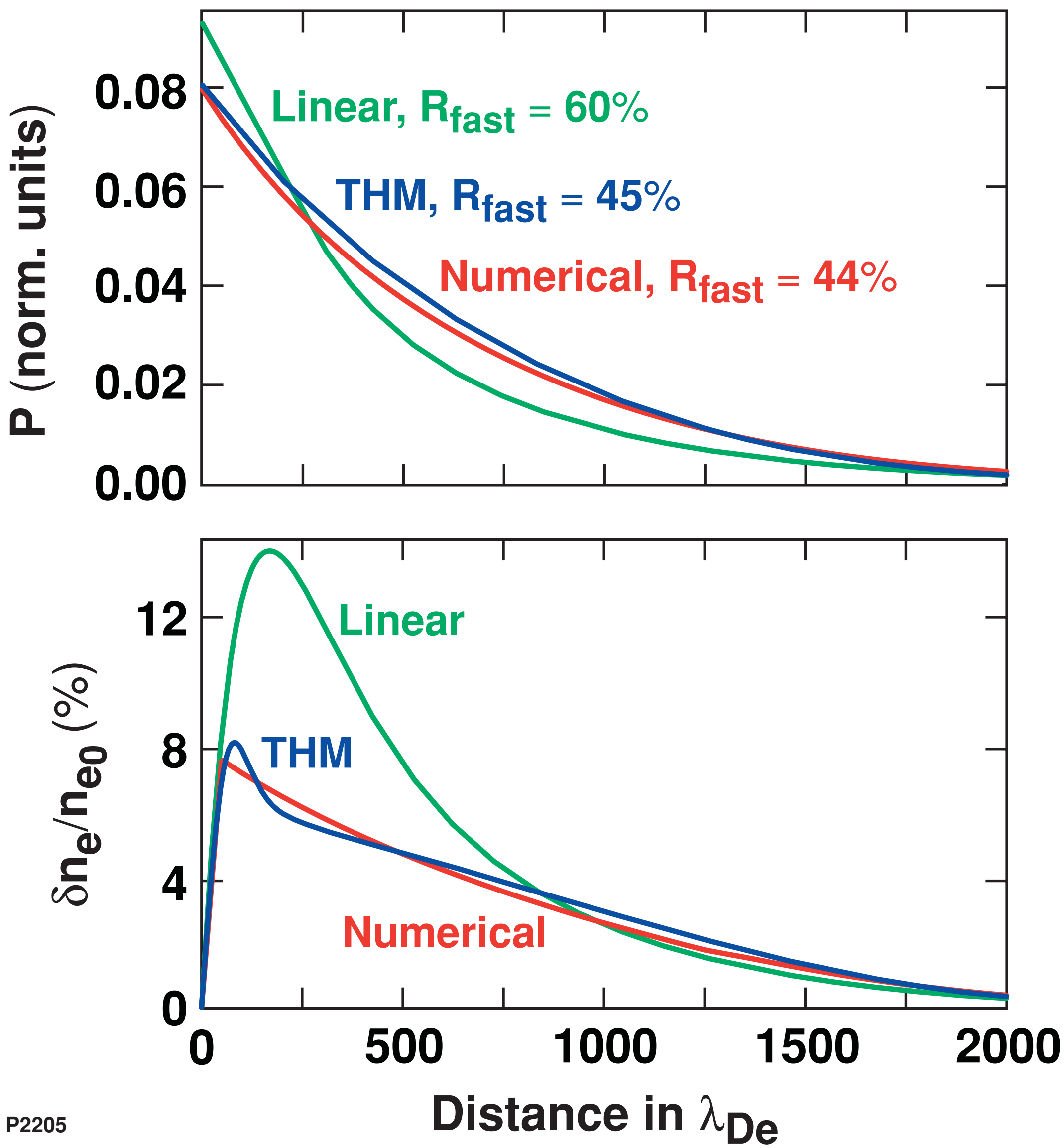
# For $T_e/T_i$ = 10, damping is small and fast-wave SBS reflectivity is large




- $\gamma/\omega_{pi} = 10^{-2} \Rightarrow R_{fast}$ = 44% IA wave amplitude is large enough to be affected by nonlinear saturation.
- The two-harmonics model[1] (THM) has been extended for two-ion plasmas.

[1] J. A. Heikkinen *et al.*, Phys. Plasmas 27, 707 (1984).

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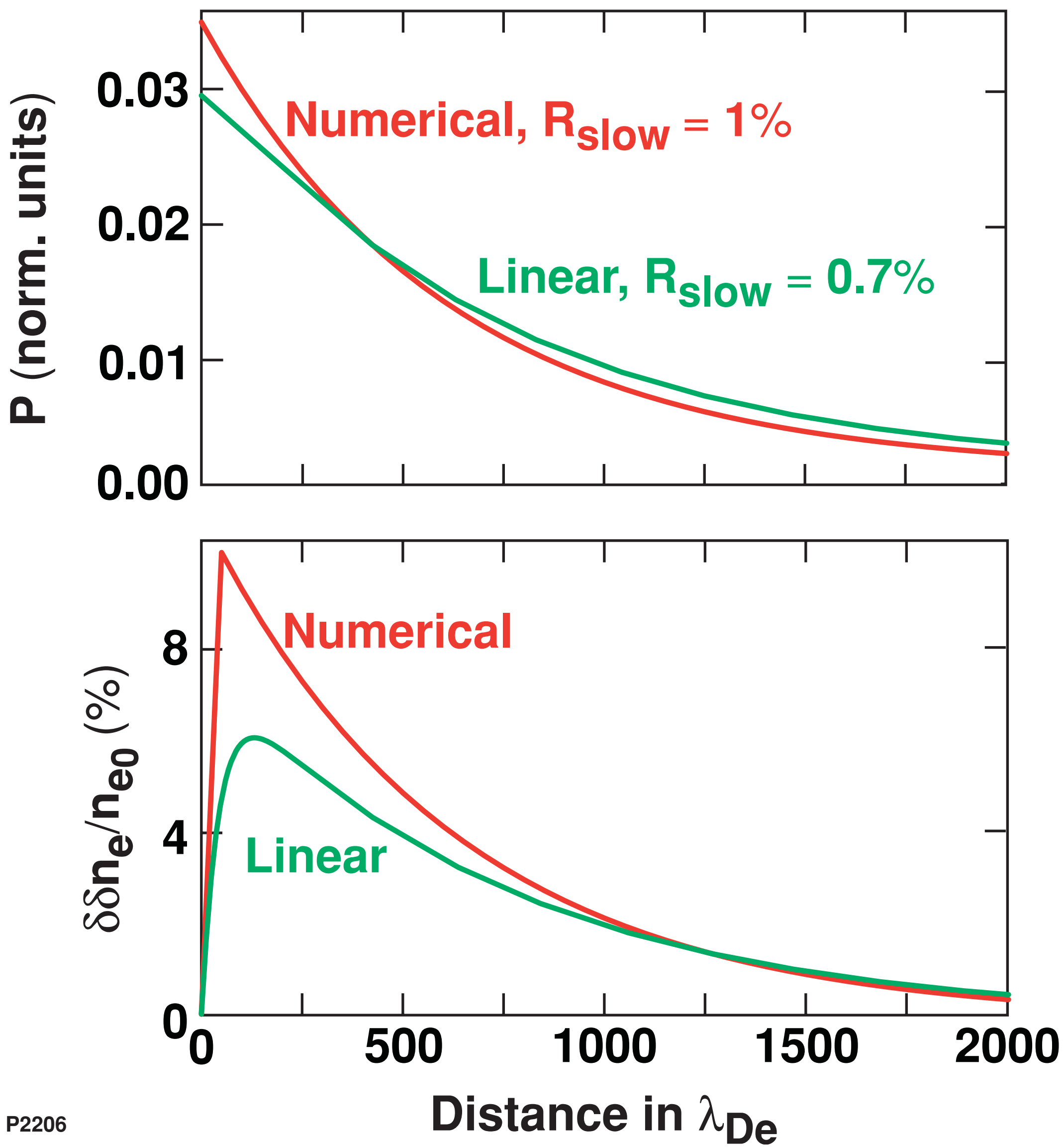
# In CH plasmas slow-wave SBS reflectivity is much smaller than fast-wave SBS reflectivity






- In slow-wave protons are pushed away from carbon ions shielding $\varphi$ and thus reducing $\delta n_e$ and $R_{slow}$.
- For $I = 2 \times 10^{15}$ W/cm$^2$, slow-wave SBS is below threshold.
- For $I = 7 \times 10^{15}$ W/cm$^2$, $T_e/T_i = 10$ $\gamma/\omega_{pi} = 10^{-2}$ and $R_{slow} = 1\%$.
- Nonlinear saturation for $\delta n_h >> \delta n_c \rightarrow$ increase in $\delta n_e$.

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- Application of our model to different component plasmas is underway