Collisional Damping of Plasma Waves on a Pure Electron Plasma*

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The collisional damping of electron plasma waves (or, more precisely, Trivelpiece-Gould waves) on a pure electron plasma column is discussed. The damping in a pure electron plasma differs from that in a neutral plasma, since there are no ions to provide collisional drag on the oscillatory motion of the electrons. A dispersion equation for the complex wave frequency is derived from Poisson’s equation and the drift-kinetic equation with the Dougherty collision operator—a Fokker-Planck operator that conserves particle number, momentum, and energy and yet is analytically tractable. The dispersion equation spans from weak collisionality to strong collisionality, matching onto results from fluid theory in the latter limit. For phase velocity comparable to the thermal velocity, Landau damping is recovered in the weakly collisional limit [1]. For larger phase velocity, where Landau damping is negligible, the dispersion equation yields the simple formula [2]

\[ \omega = \left( k_z \omega_p / k \right) \left[ 1 + (3/2)(k\lambda_D)^2(1+10i\alpha/9)(1+2i\alpha)^{-1} \right] \]

for the complex wave frequency, where \( \omega_p \) is the plasma frequency, \( k_z \) is the axial wavenumber, \( k \) is the total wavenumber, \( \lambda_D \) is the Debye length, \( \nu \) is the collision frequency, and \( \alpha \equiv \nu k / \omega_p k_z \).

Note that in the weakly collisional regime, the damping rate is given by \( \text{Im}(\omega) \approx -4\nu(k\lambda_D)^2 / 3 \), which is suppressed from the collisional damping rate in a neutral plasma \( \text{Im}(\omega) \approx -\nu / 2 \) by the small factor \((k\lambda_D)^2 \ll 1 \) [3]. This suppression reflects the conservation of electron momentum in the pure electron plasma. The damping in the pure electron plasma results from bulk viscosity, which, in turn, arises from collisional velocity scattering between parallel and perpendicular degrees of freedom.

Recent damping measurements on cold Mg\(^+\) plasmas confirm the \( T^{-1/2} \) scaling predicted by the above formula (for \( \alpha \ll 1 \)), but the observed damping rate exceeds the predicted rate by over an order of magnitude. The source of this discrepancy is currently being investigated, both theoretically and experimentally.

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