Kinetic modeling of vortex-type plasma modes carrying orbital angular momentum

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Twisted waves, or vortex-type plasma modes, carry finite orbital angular momentum (OAM) related to the helicity of the wavefront—i.e., vorticity—in addition to spin angular momentum. The OAM of laser pulses with spiral wavefronts, associated with the spatial distribution of beam intensity and phase, excites twisted density perturbations in a plasma and enables the exchange of OAM between electrostatic and electromagnetic modes [1]. In the kinetic description of twisted waves carrying OAM, it was shown that the decomposition of susceptibility into axial and poloidal components leads to two separate poles, expressed by delta functions in velocity space, valid for the resonant Landau line defined on the velocity plane [2].

Recently, we have generalized this method by introducing a new variable transformation scheme and a modified resonance condition, which extends the velocity integration space and confirms a more natural representation of wave propagation [3]. This generalized formulation, also known as the Khan–Fukuyama method, is gaining popularity in recent studies for explaining twisted plasma modes and instabilities in self-gravitating plasma systems carrying OAM [4, 5].

Here, using the kinetic formulation, we further investigate the dispersion and damping properties of electrostatic electron and ion modes under the new variable transformation scheme. This approach enables the evaluation of the imaginary part of the susceptibility through a velocity integral involving only a single pole, which includes both axial and angular contributions. As a result, the method for deriving the dispersion relation via parallel and angular decomposition of poles is improved, and a plasma dispersion function is defined. The limitation of the Landau integral, which involves integration over a resonance line, is thus removed, and the velocity space is extended. It is now possible to extend the integration space and eliminate the limitation of the JTM model presented in Ref. [2], which restricts integration to a resonance line in velocity space. Numerical analysis has been carried out, and the results—illustrating the role of OAM states on plasma dynamics and the effect of the twist parameter on kinetic plasma waves—are presented with supporting illustrations.

References

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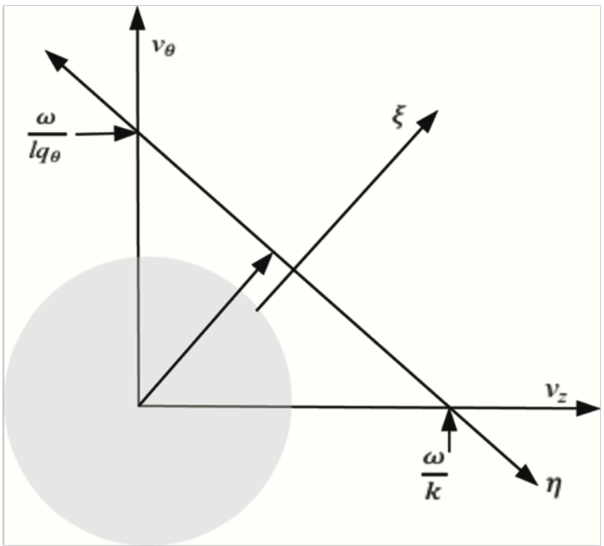

Figure 1. The modified Landau resonance region defined in the velocity space after a new variable transformation.