Coupled electrostatic wavepackets in plasmas: on the role of kappa-distributed electrons on the onset and growth rate of modulational instability.

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Electrostatic wavepackets in plasmas have been investigated with respect to the modulational instability (MI), a mechanism known from nonlinear optics that may lead to energy localization and to the emergence of localized structures (envelope solitons). For a single wave, the plasma fluid model can be reduced to a nonlinear Schrodinger (NLS) equation by using a multiple scale perturbation method [1]. The MI of propagating waves and the existence of localized wavepackets is then investigated within the NLS framework. However, co-propagation and interactions of two or more wavepackets in a plasma fluid remains largely unexplored. A pair of co-propagating electrostatic wavepackets with different carrier wavenumbers is considered in a 1D collisionless unmagnetized plasma, consisting of a cold (inertial) ion fluid and suprathermal, kappa (κ-) distributed electrons. The plasma fluid model is reduced by using a multiple scale (Newell) technique to an a-symmetric pair of coupled NLS (CNLS) equations for the respective wavepacket amplitudes. The dispersion, nonlinearity and cross-coupling coefficients have been calculated as functions of the plasma parameters and the electron spectral index (kappa) [2, 3]. A detailed MI analysis has been performed to determine the instability window and the corresponding growth rate [4, 5] and to investigate, from first principles, their dependence on the carrier wavenumbers and on the spectral index κ of the electron distribution. Space relevant values of kappa [2] in the range from 2 to 6 are adopted, in comparison with the large kappa regime for which the behavior is practically of Maxwell-Boltzmann type. A calculation of growth-rate patterns on two-dimensional parameter spaces reveals that most of the variation occurs in the range of kappa from 2 to 3. The region of kappa between 3 and 6 presents some quantitative variation but is qualitatively uniform, practically. For kappa less than 2, wave propagation is modulationally unstable in most parts of the explored parameter spaces with very large growth rates.

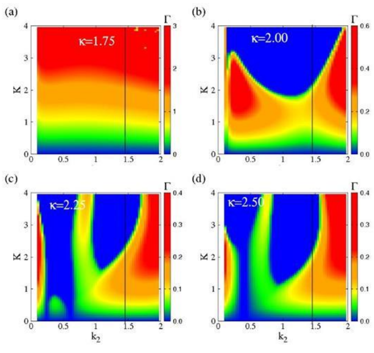

Figure 7: Maps of the growth rate Γ on the $k_2 - K$ plane for (a) $\kappa = 1.75$; (b) $\kappa = 2.00$; (c) $\kappa = 2.25$; (d) $\kappa = 2.50$. The other parameters as in Fig. 6. The vertical black-solid line indicates the boundary between two different regimes of the decoupled CNLS equations, i.e., the stable-stable regime for which $P_1Q_{11} < 0$ and $P_2Q_{22} < 0$ ($k_2 < k_r$, left from the vertical line) and the stable-unstable regime for which $P_1Q_{11} < 0$ and $P_2Q_{22} > 0$ ($k_2 > k_r$, right from the vertical line). Note that k_r depends weekly on the spectral index κ, but the differences cannot be observed in this scale.

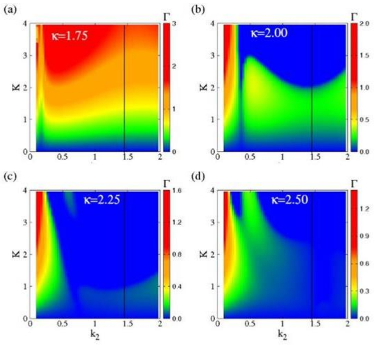

Figure 11: Maps of the growth rate Γ on the $k_2 - K$ plane for (a) $\kappa = 1.75$; (b) $\kappa = 2.00$; (c) $\kappa = 2.25$; (d) $\kappa = 2.50$. The other parameters as in Fig. 10. The vertical black-solid line indicates the boundary between two different regimes of the decoupled CNLS equations, i.e., the unstable-stable regime for which $P_1Q_{11} > 0$ and $P_2Q_{22} < 0$ ($k_2 < k_r$, left from the vertical line) and the unstable-unstable regime for which $P_1Q_{11} > 0$ and $P_2Q_{22} > 0$ ($k_2 > k_r$, right from the vertical line). Note that k_r depends weekly on the spectral index κ, but the differences cannot be observed in this scale.

Acknowledgments

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