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Modulational Instability Of Dust Electron Acoustic Waves In Superthermal Dusty Plasmas

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Abstract. In this investigation we have studied how dust concentration and superthermality of electrons affect the instability growth rate of dust electron-acoustic waves. Both type of dark and bright envelope solitons are observed.

Keywords: Instability, superthermal, envelope solitons, electron-acoustic wave.
PACS: 52.27.Lw,05,45,Yv, 52,35,Sb

Electron-acoustic waves (EAWs) having high frequency occur in plasmas are characterized by two type populations of electrons (namely, cold and hot electrons). A large number of investigations have been reported to study the characteristics of EAWs in an unmagnetized plasmas [1, 2]. Dust particles are ubiquitous component of space and astrophysical environments and their presence in a plasma has long been shown theoretically and confirmed experimentally to generate new modes [3], and also to modify the characteristics of existing ones, including the electron-acoustic (EA) mode [4, 5]. A kappa type distribution function [6] is most appropriate to model effectively the excess superthermality phenomenon. Over the last years, the study of the modulational instability (MI) of solitary waves has been a field of great interest in various plasma situations [7, 8]. Very recently, Sharmin and Kourakis [9] have studied modulational instability (MI) of electron-acoustic solitary waves in the presence of excess superthermality of electrons. Our aim is to investigate the nonlinear self-modulation of electron-acoustic waves in the presence of dust particles and excess superthermal electrons.

We adopt a fluid model, following the formalism in [9], by adding a dust species in the background. The latter affects the charge balance through Poisson's equation; investigating this effect is our scope in this brief communication. From charge neutrality at equilibrium, $n_{c0}/n_{h0} = Z_i n_{i0}/n_{h0} + sZ_d n_{d0}/n_{h0} - 1 = \alpha$. A multiple scales perturbation technique [10] is used to study the dynamics of a slowly-varying amplitude of electrostatic excitations. Details on the technique are given in Ref. [9], only final expressions are provided in this manuscript. From the first order evolution equations, we obtain the dispersion relation as $\omega^2 = k^2\alpha/(k^2 + c_1)$.

The tedious calculation will be reported in a more detailed account of our work; the long expression for the coefficient Q is omitted here. The dispersion coefficient $P = -\frac{3}{2}\frac{\omega^5 c_1}{k^4\alpha^2}$, which is a negative quantity. The expression for the nonlinearity coefficient Q, due to the carrier wave self-interaction in the background plasma is same as given in Ref. [9], by replacing β with α. For lack of space, we limit ourselves here to providing a brief account of our main results below. We obtain a nonlinear Schrödinger

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(NLS) equation, identical in structure to Eq. (19) in Ref. [9], yet now incorporating the influence of the dust presence. The expression for the growth rate identical to Eq. (27) in Ref. [9] with $\Gamma = \tilde{\omega}/(Q_\infty|\psi_0|^2)$ and $x = \tilde{k}/(Q_\infty/P_\infty)^{1/2}|\psi_0|$ with $P_\infty = P(\kappa \to \infty)$ and $Q_\infty = Q(\kappa \to \infty)$ is used to investigate the instability's dependence on superthermality (via κ) and dust concentration (via α). Figure (a) shows the variation of ω with the wave number k for different values of κ as well as dust concentration. ω decreases as the value of κ increases. Figs. (b) and (c) show the variation of the modulational instability (MI) growth rate with the effects of excess superthermality (via κ) and negative dust concentration (via α) respectively. The MI growth rate decreases with increase in superthermality as well as dust concentration. The threshold k_{cr} separates the stable region(s) ($k < k_{cr}$ or $P/Q < 0$) from the unstable one(s) ($k > k_{cr}$ or $P/Q > 0$). We have also observed that critical wave number k_{cr} where instability sets in increases with increase in superthermailty as well as negative dust concentration. The exact results of Ref. [9] are recovered in the absence of charged dust. Further, with no dust, for a very large value of κ , the results of Ref. [7] are well recovered. It is concluded that bright and dark-type envelope structures are observed and their characteristics are modified by the superthermality of electrons and dust concentration.

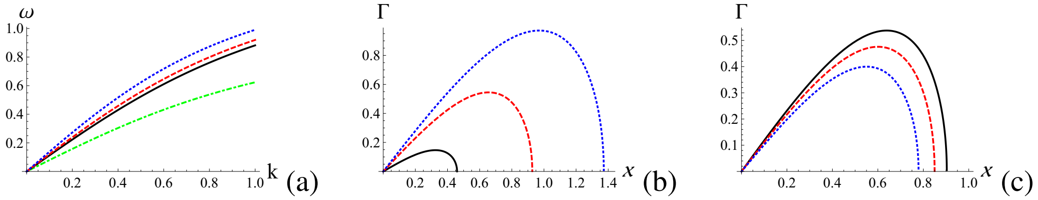

FIGURE 1. The variation of the frequency ω with wave number k (for different values of κ and dust concentration; dot-dashed: no dust; with dust, solid: $\kappa = 3.25$, dashed: $\kappa = 4.25$, Dotted: $\kappa = 25$) and growth rate Γ for different values of (b) superthermality parameter (solid: $\kappa = 3.25$, dashed: $\kappa = 4.25$, Dotted: $\kappa = 25$) and (c) dust concentration (solid $\mu_d = 0.2$, dashed: $\mu_d = 0.25$, Dotted: $\mu_d = 0.3$) .

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