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Research Article

ELECTROSTATIC SOLITARY POTENTIAL STRUCTURES IN FOUR COMPONENT DUSTY PLASMA WITH KAPPA DISTRIBUTED ELECTRONS AND IONS

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ABSTRACT

The properties of solitary waves have been investigated theoretically in unmagnetized dusty plasma consisting of positively and negatively charged dust with kappa distributed electrons and ions. The Korteweg-de Vries (K-dV) equation governing the dynamics of given plasma system has been derived using reductive perturbation method. The soliton solution derived for the K-dV equation is of the sech^2 form. Slow and fast modes are found to exist in the present plasma system in which both compressive and rarefactive solitons exist. The effects of the dusty plasma parameters and kappa parameters on the dynamics of these solitons in both modes are discussed numerically. The results are displayed graphically for the given set of parameters. The results obtained from this investigation would be useful in understanding the properties of nonlinear solitary waves in laboratory and in space dusty plasmas.

INTRODUCTION

Dusty plasmas play important role in space, astrophysical and laboratory environments. They have opened up a completely new and fascinating research area, on account of their vital applications in understanding various collective processes in space environments (Horanyi and Mendis, 1985; Goertz, 1989; Bouchule, 1999; Verheest, 2000; Verheest, 1996; Shukla, 2001; Mendis and Rosenberg, 1994; Shukla and Mamun, 2000) and laboratory devices (Barkan *et al*, 1995; Merlino *et al*, 1998; Homann *et al*, 1997). Dusty plasmas also play significant role in low temperature physics, radio frequency plasma discharge (Chu *et al*, 1994), coating and etching of thin films (Selwyn, 1993), plasma crystals (Thomas *et al*, 1994) etc. In dusty plasma, the charged particles being in random motion interact with each other through their own electromagnetic forces and also respond to externally applied perturbations. Numerous instabilities are present in plasma when the amplitude of rising perturbations is small. While at huge amplitude, the linearization process breaks down. Thus dusty plasma is inherently a nonlinear medium where a great variety of nonlinear wave phenomena like solitons, shocks and vortices arise. Solitary wave is a nonlinear wave which maintains its shape during its propagation. It's formation takes place because of balance between the effects of the nonlinearity and the dispersion. The theoretical and experimental study of solitary waves in dusty plasma is done by many researchers and scholars. Rao *et al* (1990) were the first to study the existence of dust-acoustic waves (DAWs) and Barkan *et al* (1995) gave the experimental verification of them. Dust grains in dusty plasma are usually of negatively charged because of the propagation of ions and electron currents on their surfaces. Dusty plasmas containing grains of opposite polarity had been studied theoretically (Sakanka and Shukla, 2000; Angelo, 2001; Angelo, 2002; Mamun and Shukla, 2002; Sayad and Mamun, 2007) and experimentally (Horanyi *et al*, 1993; Mendis and Rosenberg, 1994; Horanyi, 1996; Mendis, 2002) by many authors. Mamun *et al* (1996) studied dusty plasma with Boltzmann distributed ions and inertial dust fluid. They found only negative solitary potentials linked with nonlinear dust-acoustic waves. They also found that the potential polarity of the dust-acoustic solitons is different from the normal ion-acoustic solitons in electron-ion plasma. Dust-acoustic solitary waves in the one-dimensional and unmagnetized plasma have also been investigated by Mahmood and Saleem (2003). Chow *et al* (1993) explained the situations under which smaller dust particles become positively charged and larger particles become negatively charged. The properties of dust acoustic

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solitary waves in warm dusty plasma were studied by Pakzad (2011). It was found that both compressive and rarefactive solitons in warm dusty plasma can be propagated.

For the first time, Kappa velocity distributions functions were given by Vasyliunas (1968) for electrons in the magnetosphere as measured by satellites OGO 1 and OGO 3. The isotropic three-dimensional (3D) kappa velocity distribution of particles of mass m is of the form

$$F_k(v) = \frac{\Gamma(\kappa+1)}{(\Pi\kappa\theta^2)\Gamma(\kappa-1/2)}\left(1+\frac{v^2}{\kappa\theta^2}\right)^{-(\kappa+1)}$$

Where θ is the most probable speed related to the usual thermal velocity $V_t = (K_B T/m)^{1/2}$ by $\theta = [(2\kappa-3)/\kappa]V_t$, T being the characteristic kinetic temperature, i.e., the temperature of the equivalent Maxwellian with the same average kinetic energy and K_B is the Boltzmann constant. The kappa distribution is defined for $\kappa > 3/2$. The κ is the spectral index, which is measure of the slope of energy spectrum of the superthermal particles forming the tail of velocity distribution function and, thus allows for a family of power law like distribution. The kappa distribution provides alternate for the Maxwell distribution. Low values of κ represent hard spectrum with a strong non-Maxwellian (power law - like) tail, an enhanced velocity distribution at low speeds and a depressed distribution is recovered. Rahmann (2017) investigated the dust ion acoustic solitary and shock waves in unmagnetized dusty plasma with kappa distributed superthermal electrons. It was found that the presence of stationary dust particles and superthermality of electrons play important role in changing the phase speed, amplitude and width of solitary and shock waves. Alam *et al* (2013) have studied the effect of bi-kappa distributed electrons on the nonlinear propagation of dust ion acoustic (DIA) shock waves in dusty superthermal plasmas. They have investigated the effects of ion kinematic viscosity and the superthermal two temperature electrons. Dust acoustic double layers in a four component dusty plasma have been studied studied by Mandal *et al* (2009). Roychoudhury and Mukherjee (1997) showed that, finite dust temperature has major role for determining the region for the existence of nonlinear solitary waves. Because of orbital effects or thermalization with the ions, the dust has temperature in dusty plasma.

In this paper, the dynamics of electrostatic solitary potential structures is studied in plasma system consisting of positively charged warm adiabatic dust and negatively charged cold dust with ions and electrons obeying kappa distribution. Regarding the organization of the paper, basic equations of theoretical model and derivation of K-dV equation associated to solitary structures, discussion of numerical results and conclusion are presented.

Basic Equations And Derivation Of K-dV Equation

Let us consider four component weakly coupled unmagnetized dusty plasma made of positively charged warm adiabatic dust and negatively charged cold dust with both kappa distributed ions and electrons have been considered here. The basic set of normalized fluid equations describes the propagation of solitary waves in such dusty plasma system (Gill *et al*, 2011).

For negative dust

$$\frac{\partial N_1}{\partial t} + \frac{\partial (N_1 U_1)}{\partial x} = 0 \tag{1}$$

$$\frac{\partial U_1}{\partial t} + U_1\frac{\partial U_1}{\partial x} = \frac{\partial \psi}{\partial x} \tag{2}$$

For positive dust

$$\frac{\partial N_2}{\partial t} + \frac{\partial (N_2 U_2)}{\partial x} = 0 \tag{3}$$

$$\frac{\partial U_2}{\partial t} + U_2\frac{\partial U_2}{\partial x} = -\alpha\left(\frac{\partial \psi}{\partial x} + \frac{\sigma_d}{N_2}\frac{\partial P_2}{\partial x}\right) \tag{4}$$

and

$$\frac{\partial P_2}{\partial t} + U_2\frac{\partial P_2}{\partial x} + 3P_2\frac{\partial U_2}{\partial x} = 0 \tag{5}$$

Poisson equation

$$\frac{\partial^2 \psi}{\partial x^2} = N_1 - \mu_2 N_2 + \mu_e n_e - \mu_i n_i \tag{6}$$

Where N_1 and N_2 are the negatively charged and positively charged dust number densities normalized by the equilibrium values n_{10} and n_{20} respectively. U_1 and U_2 are negative and positive dust fluid speed normalized by $C_1 = [Z_1 k_B T_i/m_1]^{1/2}$, Ψ is the wave potential which is normalized by $\frac{k_B T_i}{e}$ and dust density ratio $\alpha = \frac{Z_2 m_1}{Z_1 m_2}$. P_2 is the thermal pressure of positive dust fluid normalized by its equilibrium value $n_{20}k_B T_d$. Dust temperature ratio $\sigma_d = \frac{T_d}{Z_2 T_i}$, electron density $\mu_e = \frac{n_{e0}}{Z_1 n_{10}}$, ion density $\mu_i = \frac{n_{i0}}{Z_1 n_{10}}$ and $\sigma = \frac{T_i}{T_e}$. Where k_B is the Boltzmann constant, e is the charge on electron; Z_1 and Z_2 are the number of electrons and protons residing on a negative and positive dust; m_1 and m_2 are the mass of negative and positive dust particle; T_d, T_i, T_e are temperature of positive charged dust, ions and electrons respectively. The number density of electrons and ions, with kappa distribution is given by

$$n_{e,i} = \left[1 \mp \frac{p\psi}{\kappa_{e,i} - \frac{3}{2}}\right]^{-(\kappa_{e,i} - \frac{1}{2})} \tag{7}$$

Where $p = 1$ for ion density & κ_i and κ_e are called kappa indices of ions and electrons respectively. Linearizing the equations (1) – (6), we get the dispersion relation in terms of ω and k, as given below

$$\omega^2 = \frac{k^2\left(1+\alpha\mu_2+3\alpha\sigma_d c_1 \pm \sqrt{(1+\alpha\mu_2+3\alpha\sigma_d c_1)^2-12\alpha\sigma_d c_1}\right)}{2c_1} \quad (8)$$

Where $c_1 = b_1\mu_i + a_1\mu_e + k^2$

Clearly we get two roots of ω that correspond to fast and slow modes. To study the effect of propagation constant on the carrier wave frequency of both modes, we have plotted carrier wave frequency *(ω)* as a function of propagation constant *(k)* for different values of kappa indices of ions *(κ_i)* and electrons *(κ_e)* (Fig 1 and Fig 2). Here different values of kappa indices of ions *(κ_i)* and electrons *(κ_e)* are taken as $\kappa_i = 2, 3, 5$ (Fig 1) and $\kappa_e = 2, 3, 5$ (Fig 2). The different parameters are taken as $\mu_i = 0.8$, $\mu_e = 0.2$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$. From these Figures, it is observed that for fast mode, the carrier wave frequency increase with increase in spectral indices of ions *(κ_i)* and electrons *(κ_e)* but for slow mode, it remains constant. This behaviour of carrier wave frequency for distribution parameter is exact similar to that observed by Bains *et al* (2013). Thus the propagation characteristics of the fast solitary potential structures are affected by kappa distribution of particles, while slow potential structures have no effect of kappa distribution.

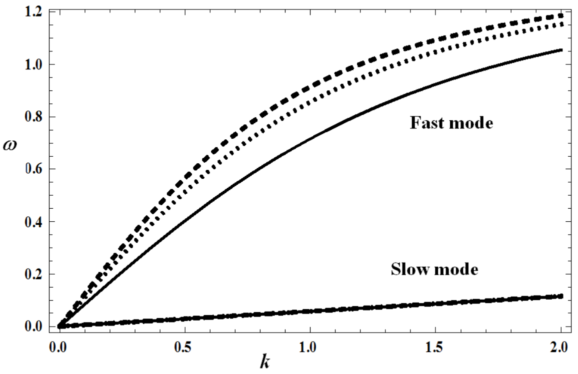

Figure 1 Variation of carrier wave frequency *(ω)* with propagation constant *(k)* for fast and slow mode for three different values of $\kappa_i = 2$ (solid line), $\kappa_i = 3$ (dotted line), $\kappa_i = 5$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_e = 5$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

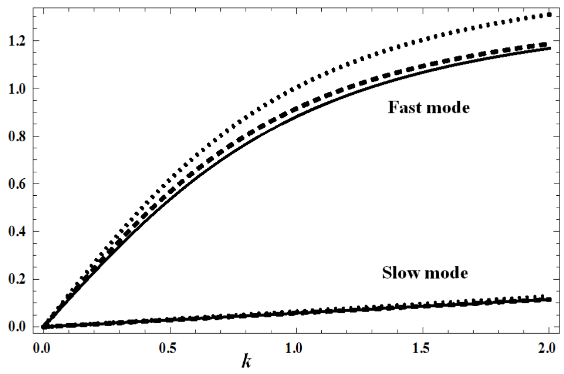

Figure 2 Variation of carrier wave frequency *(ω)* with propagation constant *(k)* for fast and slow mode for three different values of $\kappa_e = 2$ (solid line), $\kappa_e = 3$ (dotted line), $\kappa_e = 5$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_i = 5$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

To investigate the behavior of solitary waves in dusty plasma, we employ reductive perturbation method. According to this method, we use stretched coordinates given by Gardner and Morikawa (1960) [38] (using α = 1/2) as $\tau = \varepsilon^{\frac{3}{2}} t$ and $\xi = \varepsilon^{\frac{1}{2}}(x - \lambda t)$

Where λ is the wave phase velocity and ε is a small parameter. The dependent variables are expended as

$$S = S_0 + \sum_{n1}^{\infty} \varepsilon^n S_1^{(n)} \quad (9)$$

Where $S = N_1, N_2, P_2, U_1, U_2, \Psi$ and $S_0 = 1, 1, 1, 0, 0, 0$ using stretched coordinates and perturbation expression (9) the poisson equation gives the following dispersion relation

$$\lambda^2 = \frac{(1+\alpha\mu_2+3\alpha\sigma_d c_2) \pm \sqrt{(1+\alpha\mu_2+3\alpha\sigma_d c_2)^2-12\alpha\sigma_d c_2}}{2c_2} \quad (10)$$

The dispersion relation (10) is the phase velocity *(λ)* of solitary potential structures. λ with positive sign represents phase velocity of fast mode (λ_f) and with negative sign represents the phase velocity of slow mode *(λ_s)* respectively. The variation of the phase velocity of fast mode *(λ_f)* with the spectral indices of ions *(κ_i)* and electrons *(κ_e)* for different values of ion to electron temperature ratio *(σ)* are explored (Fig 3 and Fig 4). The other parameters are taken as $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_e = 3$, $\sigma_d = 0.001$ and $\alpha = 2$ for three different values of $\sigma = 0.5, 0.7, 0.9$. For given value of σ, the phase velocity of fast mode increases with the increase in spectral indices of ions *(κ_i)* and electrons *(κ_e)*. This behaviour of phase velocity for kappa index of electrons is similar to that observed by Alam *et al* (2014). It can be said that spectral indices (κ_i and κ_e) play an important role on the phase velocity of solitary waves. For given values of spectral indices of ions *(κ_i)* and electrons *(κ_e)*, the increase in ion to electron temperature ratio *(σ)* causes the decrease in phase velocity of fast mode.

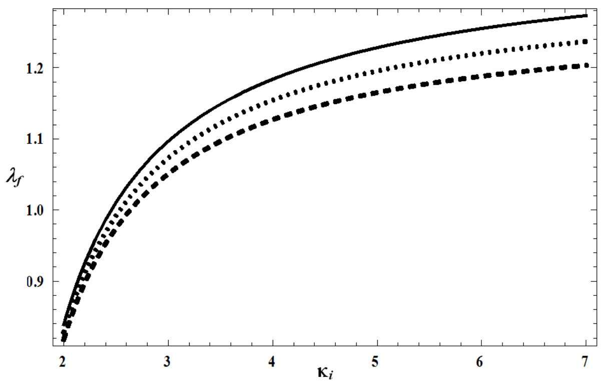

Figure 3 Variation of phase velocity of fast mode *(λ_f)* with spectral index of ions *(κ_i)* for three different values of $\sigma = 0.5$ (solid line), $\sigma = 0.7$ (dotted line), $\sigma = 0.9$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_e = 3$, $\sigma_d = 0.001$ and $\alpha = 2$

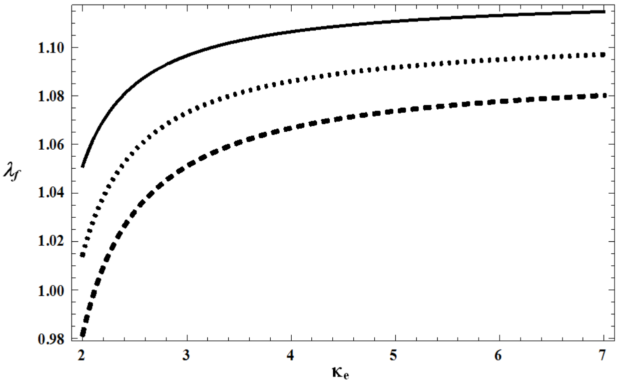

Figure 4 Variation of phase velocity of fast mode (λ_f) with spectral index of electrons (κ_e) for three different values of $\sigma = 0.5$ (solid line), $\sigma = 0.7$ (dotted line), $\sigma = 0.9$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_i = 3$, $\sigma_d = 0.001$ and α=2.

The phase velocity of slow mode also increases with increase in spectral indices of ions and electrons and decreases with increase in ion to electron temperature ratio (not shown here). Considering the next-order in ε, we obtain a system of equations in second-order of perturbed quantities. Solving this system of equations, we obtain the following K-dV equation

$$\frac{\partial \psi}{\partial \tau} + A\psi \frac{\partial \psi}{\partial \xi} + B\frac{\partial^3 \psi}{\partial \xi^3} = 0 \tag{11}$$

Where A is nonlinear and B is dispersion coefficient and are given as

$$A = \left[-\frac{3}{\lambda^4} + \frac{3\mu_2\alpha^2\left(\lambda^2 - 2\alpha\sigma_d + 3\sigma_d\right)}{\left(\lambda^2 - 3\alpha\sigma_d\right)^3} - 2\mu_e a_2\sigma^2 + 2\mu_i b_2\right]\left[\frac{\lambda^3\left(\lambda^2 - 3\alpha\sigma_d\right)^2}{2\left(\lambda^2 - 3\alpha\sigma_d\right)^2 + 2\mu_2\alpha\lambda^4}\right] \tag{12}$$

$$B = \left[\frac{\lambda^3\left(\lambda^2 - 3\alpha\sigma_d\right)^2}{2\left(\lambda^2 - 3\alpha\sigma_d\right)^2 + 2\mu_2\alpha\lambda^4}\right] \tag{13}$$

The steady state solution of K-dV equation (11) is obtained by transformation of the independent variables ξ and τ as $\eta = \xi - v\tau$ (where v is constant speed normalized by C_1) and imposing boundary conditions (viz. $\psi \to 0, \frac{\partial \psi}{\partial \eta} \to 0, \frac{\partial^2 \psi}{\partial \eta^2} \to 0$ at $\eta \to \pm\infty$). The wave solution is

$$\psi = \psi_0 \sec h^2\left(\frac{\eta}{\Delta}\right) \tag{14}$$

Where the amplitude ψ_0 and width Δ of solitons is given by

$$\psi_0 = \frac{3v}{A} \quad \text{and} \quad \Delta = \sqrt{\frac{4B}{v}}$$

As observed from equation (12) and (13), A and B are the functions of various parameters including kappa indices of ions and electrons , dust temperature ratio, dust density ratio and ion to electron temperature ratio. Hence the effect of these parameters will be discussed in detail in the next section.

DISCUSSION OF NUMERICAL RESULTS

We have investigated the effects of kappa distributed electrons and ions, dust temperature ratio and dust density ratio on the wave propagation of solitary waves in dusty plasma. To describe the nonlinear propagation of the solitary waves, we have derived a K-dV equation (11) by using Reductive Perturbation Method and obtained solitary wave solution. From the value of phase velocity given by equation (10), it is clear that we have two types of wave modes (Fast and Slow wave mode) in dusty plasma system.

Fast mode analysis

Contour plot of nonlinear coefficient A for fast mode in μ_i -μ_e space for three different values of dust temperature ratio (σ_d) keeping other parameters as $\kappa_i = 2$, $\kappa_e = 3$, $\sigma = 0.5$ and $\alpha = 2$ (Fig 5).

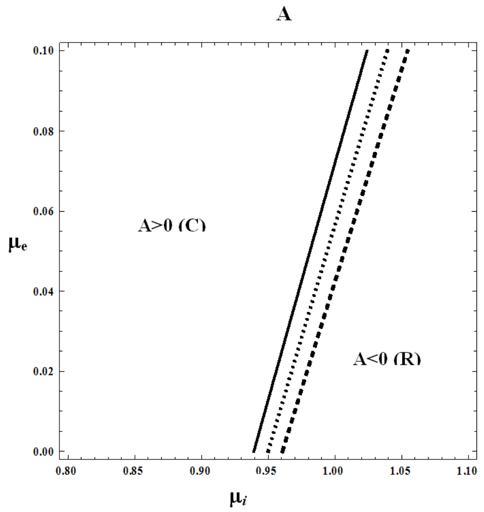

Figure 5 Contour plot of nonlinear coefficient (A) for fast mode in $\mu_i - \mu_e$ space for three different values of $\sigma_d = 0.001$ (solid line), $\sigma_d = 0.007$ (dotted line), $\sigma_d = 0.013$ (dashed line) with $\kappa_i = 2$, $\kappa_e = 3$, $\sigma = 0.5$ and $\alpha = 2$.

For given μ_e , a transition from compressive to rarefactive potential structures takes place. The region $A > 0$ (C-region) corresponds to positive potential structures or compressive solitons and $A < 0$ (R - Region) negative potential structures or rarefactive solitons respectively. The region of compressive soliton increases with increase in dust temperature ratio (σ_d) This is to be mentioned here that our result is completely in agreement with findings of Pakzad (2011).

The effect of spectral index of ions and electrons in C- region is depicted (Fig 6). Here a plot of peak amplitude of fast solitary potential structures has been given as a function of κ_i for three different values of κ_e= 2, 3, 5. The peak amplitude Ψ_{0f} increase with spectral index of ions and decrease with spectral index of electrons. An exactly a similar kind of bahaviour is observed for R-region (not shown here). It may be mentioned that this behaviour is in agreement with Alam *et al* (2013).

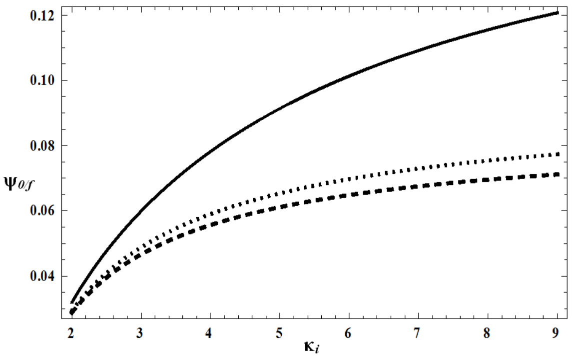

Figure 6 Variation of amplitude for fast mode *($\Psi_{0/f}$)* with spectral index of ions *(κ_i)* for three different values of $\kappa_e = 2$ (solid line), $\kappa_e = 3$ (dotted line), $\kappa_e = 5$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha=2$.

In order to investigate the effect of dust temperature and dust grain density, a plot of $\Psi_{0/f}$ Vs. σ_d has been displayed in Fig 7, the other parameters are taken as with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_i = 3$, $\kappa_e = 5$, $\sigma = 0.5$ for three different values of $\alpha = 2, 2.2, 2.4$.

From Fig 7, the peak amplitude of fast solitary structures in *C*-region decreases with dust grain density ratio *(α)* and dust temperature ratio *(σ_d)*. The behaviour of rarefactive fast solitons for parameters α and σ_d is same as for compressive solitons (not shown here). The decrease in amplitude of solitons for dust grain density ratio *(α)* is also observed by Chatterjee *et al* (2009) and Gill *et al* (2011).

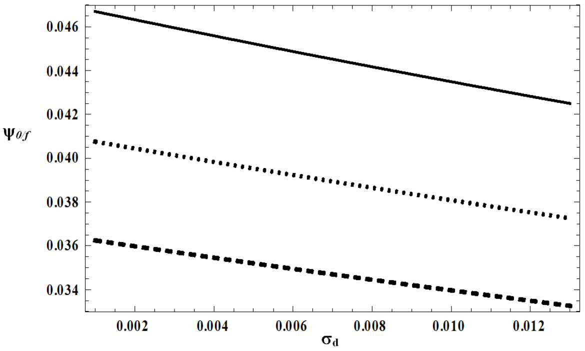

Figure 7 Variation of amplitude for fast mode *($\Psi_{0/f}$)* with dust temperature ratio *(σ_d)* for three different values of $\alpha = 2$ (solid line), $\alpha = 2.2$ (dotted line), $\alpha = 2.4$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_i = 3$, $\kappa_e = 5$ and $\sigma = 0.5$.

Slow mode analysis

Region plot of nonlinear coefficient *(A)* for slow mode in $\mu_i - \mu_e$ space is shown in the Fig 8 keeping other parameters as $\kappa_i = 2$, $\kappa_e = 3$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

For given μ_e, a transition from rarefactive to compressive potential structures takes place. The shaded portion corresponds to $A < 0$ (*R*-region) and white portion to $A > 0$ (*C*-Region) respectively. The behaviour of transition is just opposite to that observed for fast mode. The shaded region *R (A < 0)* corresponds to negative potential structures or rarefactive solitons while region *C (A > 0)* corresponds to positive potential structures or compressive solitons. The region of rarefactive solitons is not affected with rise in dust temperature ratio *(σ_d)* for slow mode.

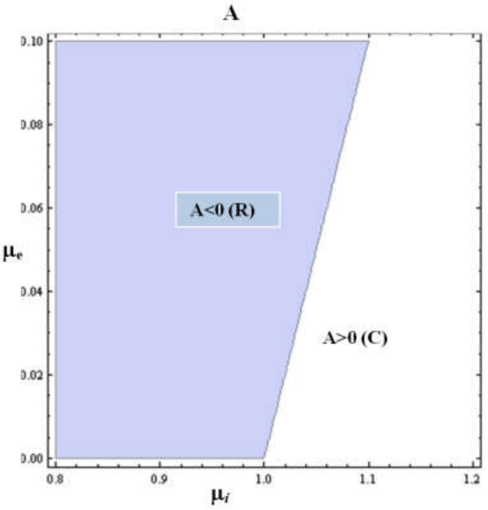

Figure 8 Contour plot of nonlinear coefficient *(A)* for slow mode in μ_i - μ_e space for three different values of $\kappa_i = 2$, $\kappa_e = 3$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

For *C*-region, a plot of peak amplitude of solitary potential structures $\Psi_{0/s}$ as a function of spectral index of ions κ_i has been given in Fig 9 for three different values of $\kappa_e = 1.6, 1.7, 1.9$. The other parameters are kept as $\mu_i = 1.1$, $\mu_e = 0.02$, $\sigma = 0.5$, $\sigma_d = 0.001$, $\alpha = 2$. From the Figure 9, the peak amplitude decreases with increase in κ_i *and* κ_e. It may be noted that this behaviour is similar to that increased for fast mode potential structures in *C*-region.

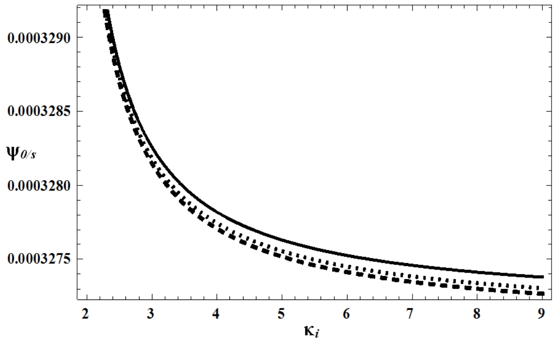

Figure 9 Variation of amplitude for slow mode *($\Psi_{0/s}$)* with spectral index of ions *(κ_i)* for three different values of $\kappa_e = 1.6$ (solid line), $\kappa_e = 1.7$ (dotted line), $\kappa_e = 1.9$ (dashed line) with $\mu_i = 1.1$, $\mu_e = 0.02$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

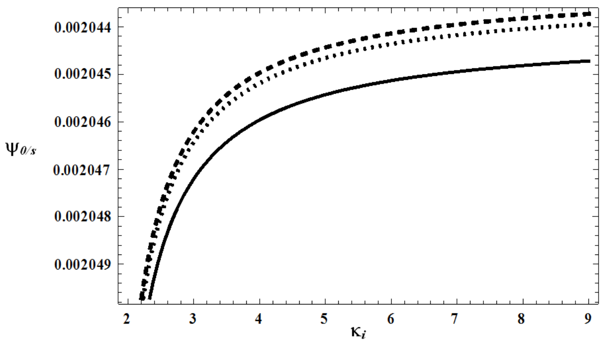

Figure 10 Variation of amplitude for slow mode *($\Psi_{0/s}$)* with spectral index of ions *(κ_i)* for three different values of $\kappa_e = 2$ (solid line), $\kappa_e = 3$ (dotted line), $\kappa_e = 5$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\sigma = 0.5$, $\sigma_d = 0.001$ and $\alpha = 2$.

However for *R*-region, the amplitude of rarefactive solitons increases with increase in spectral indices of ions (κ_i) and electrons (κ_e) as shown in Fig 10. This behaviour is similar to that observed by Alam *et al* (2013). Both slow and fast rarefactive solitary structures have similar behaviour for spectral index of ions (κ_i) and opposite behaviour for spectral index of electrons (κ_e).

To investigate the effect of dust temperature ratio and dust grain density on the dynamics of solitary potential structures in slow mode, we have plotted peak amplitude are function of dust temperature ratio (σ_d) for three different values of α in Fig 11 (*C*-region) and Fig 12 (*R*-region) respectively.

For *C*-region, the amplitude of potential structures increase with dust temperature ratio (σ_d) and dust grain density ratio (α). This behaviour is opposite to the one obtained for fast mode. It is further mentioned that the behaviour of dust grain density ratio is opposite to that observed by Chatterjee *et al* (2009) and Gill *et al* (2011).

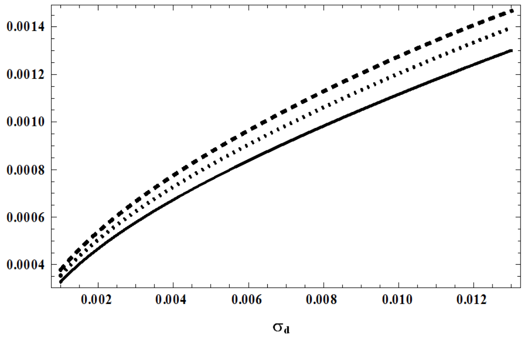

Figure 11 Variation of amplitude for slow mode $(\Psi_{0/s})$ with dust temperature ratio (σ_d) for three different values of $\alpha = 2$ (solid line), $\alpha = 2.2$ (dotted line), $\alpha = 2.4$ (dashed line) with $\mu_i = 1.1$, $\mu_e = 0.02$, $\kappa_i = 3$, $\kappa_e = 5$ and $\sigma = 0.5$.

However, from the similar plot for *R*-region (as shown in Fig 12) an entirely opposite trend is observed. Here peak amplitude decreases with both σ_d and α. In other words, we can say this region of *R*-region is similar to one obtained in case of fast mode. A similar kind of behaviour is also observed by El-Hanbaly *et al* (2016) in their investigations.

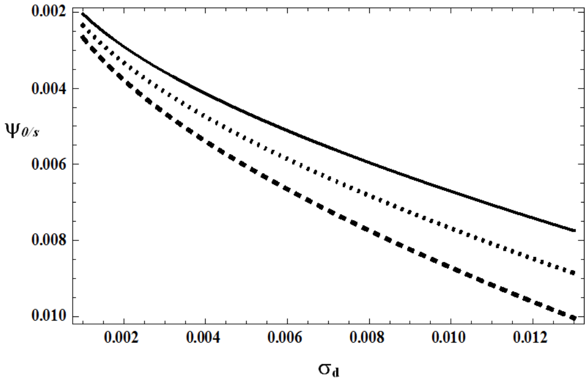

Figure 12 Variation of amplitude for slow mode $(\Psi_{0/s})$ with dust temperature ratio (σ_d) for three different values of $\alpha = 2$ (solid line), $\alpha = 2.2$ (dotted line), $\alpha = 2.4$ (dashed line) with $\mu_i = 0.8$, $\mu_e = 0.2$, $\kappa_i = 3$, $\kappa_e = 5$ and $\sigma = 0.5$.

CONCLUSIONS

In this paper, we have considered an unmagnetized dusty plasma system made of positively charged warm adiabatic dust and negatively charged cold dust with both kappa distributed ions and electrons. The properties of solitary waves in dusty plasma are discussed numerically.

The important findings that we obtained from our investigation can be summarized as follows

1. The present dusty plasma model supports both compressive and rarefactive solitary waves in fast and slow mode.
2. The carrier wave frequency of fast and slow mode increases with increase in wave propagation constant.
3. The carrier wave frequency of fast mode increase with increase in kappa indices of electrons and ions. But there is no effect of kappa parameters on carrier wave frequency of slow mode.
4. The phase velocity of both fast and slow modes increases with increase in kappa indices of ions and electrons and decreases with increase in ion to electron temperature ratio.
5. For fast mode, the transition from compressive to rarefactive solitons takes place. The amplitude of both compressive and rarefactive solitons increases with increase in kappa index of ions and decreases with increase in kappa indices of ions and electrons. It decreases with increase in dust temperature ratio and dust density ratio.
6. For slow mode, the transition from rarefactive to compressive solitons takes place. The amplitude of compressive solitons decreases with increase in kappa indices of ions and electrons; increases with increase in dust temperature ratio and dust density ratio while the amplitude of rarefactive solitons increases with increase in kappa indices of ions and electrons but decreases with increase in dust temperature ratio and dust density ratio. It decreases with increase in dust temperature ratio and dust density ratio.

The results which, have been obtained from this investigation, would be useful in understanding the properties of solitary potential structures in laboratory and in space dusty plasmas. The present results may be useful for understanding the existence of nonlinear potential structures that are observed in different regions of space (viz. solar wind, interstellar medium, auroral zone) and in laboratory dusty plasma devices.

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