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Ion acoustic solitary waves in an adiabatic dusty plasma: Roles of superthermal electrons, ion loss and ionization

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We investigate propagation of dust ion acoustic solitary wave (DIASW) in a multicomponent dusty plasma with adiabatic ions, superthermal electrons, and stationary dust. The reductive perturbation method is employed to derive the damped Korteweg–de Vries (DKdV) equation which describes DIASW. The result reveals that the adiabaticity of ions significantly modifies the basic features of the DIASW. The ionization effect makes the solitary wave grow, while collisions reduce the growth rate and even lead to the damping. With the increases in ionization cross section $\Delta\sigma/\sigma_0$, ion-to-electron density ratio δ_{ie} and superthermal electrons parameter κ, the effect of ionization on DIASW enhances.

Keywords: dust ion acoustic wave, solitary wave, ionization, adiabatic process

PACS: 52.25.Jm, 52.35.Mw, 94.05.Fg, 94.05.Bf **DOI:** 10.1088/1674-1056/ad47e4

1. Introduction

There has been a rapidly growing interest in research of dusty plasmas in the last decades.[1–3] In 1990, Rao *et al.*[4] first predicted the existence of dust acoustic waves (DAWs) in theory and derived the dispersion relationship of DAWs. Shukla *et al.*[5] further proposed that there is another type of waves in dusty plasma, namely dust ion acoustic waves (DIAWs). In 1995, Barkan *et al.*[6,7] observed the presence of DAWs and DIAWs in experiments and confirmed the theoretical predictions.

Numerous observations have shown that in space plasmas, such as the magnetosphere,[8] solar wind,[9,10] and interstellar media,[11,12] there is a high energy tail in particles distribution. In order to better describe the high energy tail, Vasyliunas[13] first proposed the Kappa distribution in 1968 and the obtained results are consistent with the electron distribution in the magnetic sheath. Afterwards, the wave modes in plasma with the consideration Kappa distributed particles were investigated extensively.[14–21] In general, increase in electron or ion superthermal index κ leads to enhancement of amplitudes of dust acoustic solitary wave (DASW),[16,17] electron acoustic solitary wave (EASW),[18] ion acoustic solitary wave (IASW),[19] and DIASW.[20] Furthermore, Mayout *et al.*[20] found that amplitude of DIASW decays more rapidly with decrease in the electron superthermal index κ. Ali[21] found that amplitude and width of DIASW grow with increasing (decreasing) electron superthermal index κ when dust concentration is lower (higher) than a critical value.

In space plasma physics, the characteristics of DIAWs in the presence of effects of ionization, ion–neutral, ion–dust, and dust–neutral collisions with dust grains attracted widespread attention. In the linear theory, DIAWs and DAWs in the dusty plasma can be excited on account of the ionization instability, and the presence of negatively charged dust makes both the frequency and the growth rate of the DIAW increase.[22–24] The nonlinear analysis of DIAW shows that the DIASWs in such a dusty plasma are weakly dissipative in nature and are governed by a modified form of the Korteweg–de Vries equation.[25–28] Ghosh[25] found that ionization instability leads to exponential growth of the DIASW's amplitude with time, whereas ion–dust and ion–neutral collisions reduce the growth rate. Tamang[28] found that ion–dust collisional frequency, ion–neutral collisional frequency, and ion loss rate not only significantly affect the dynamics of the perturbed DIAWs, but also play a pivotal role in the transition from quasiperiodic and chaotic motions to periodic motion.

These works are only valid for isothermal or cold dust, electrons and ions.[16,17,20–28] The effects of adiabatic constituent on the dusty plasma have been investigated by a number of researchers.[29–35] Alotaibi[31] investigated the dispersion characteristics of dust acoustic waves in a weakly collisional dusty plasma comprising warm adiabatic fluid dust particles, isothermal electrons and ions, and obtained the blast, anti-kink, and elliptical cosine waves. Mamun *et al.*[32–34] found that the effects of the adiabaticity of electrons and ions significantly modify the basic features (polarity, speed, amplitude, and width) of the DIASW and DASW based on different dusty plasma models. Rahman *et al.*[35] found that the phase speed of the DASHWs (dust acoustic shock waves) increases with the increase of the adiabatic index. However, research of DIASW in dusty plasmas with superthermal electrons and

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adiabatic ions under the influence of ionization effects remains unexplored.

In this work, the superthermal electrons, adiabatic ions and heavy negative dust grains are considered to construct this model. The Kappa distribution fits well with the distribution of electrons in nonequilibrium space plasmas,[8–12] and it is a more generalized distribution function than the Boltzmann distribution: the Kappa distribution returns to the Boltzmann distribution when the superthermal parameter κ approaches infinity.[16] For solitary waves where the dust dynamics plays a role, the lighter plasma particles (electrons) can be assumed to be Kappa distributed without great loss of accuracy. Usually, the ions are named as adiabatic ions when researchers introduced the ion adiabatic index γ_i.[34,35] The assumption of adiabatic ion is more appropriate when the thermodynamic process of the ions cannot be determined, as the adiabatic and isothermal processes of one-dimensional ions corresponding to the adiabatic index $\gamma_i = 3$ and 1, respectively. Due to the very large inertia, the heavy negative dust would be treated to be cold and the thermal pressure is neglected.[25] In addition, a wide range of dust plasma parameters are intended to be used in our investigation to obtain a more comprehensive understanding of the DIASW's fundamental characteristics in space and laboratory collision dust plasma environments, such as the Lunar ionosphere,[12] earth noctilucent cloud,[36] solar zodiacal dust cloud,[37] and so on. The paper is constructed as follows: in Section 2, the damped Korteweg–de Vries (DKdV) equation is obtained by employing the reductive perturbation method, and the soliton solutions are discussed. In Section 3 we present the effects of ion-to-electron temperature ratio σ_i, ion-to-electron density ratio δ_{ie}, superthermal electrons parameter κ, and and other parameters on the solitary wave solution of the DKdV equation. Section 4 is devoted to conclusion.

2. Theoretical method

Considering a three-component collisional, unmagnetized dusty plasma consisting of adiabatic ions, superthermal electrons following Kappa distribution and negatively charged dust particles. Due to the large inertia of dust particles, it assumes that the dust particles are stationary and the number of charges carried by dust particles remains constant. The ions undergo elastic collisions with the dust grains and background neutral particles. In the equilibrium situation, the charge neutrality condition becomes

$$n_{e0} + z_d n_{d0} = n_{i0}, \tag{1}$$

where n_{i0}, n_{e0}, and n_{d0} denote the equilibrium number densities of ions, electrons, and dust particles, respectively; z_d denotes the dust grain charge number. Therefore, the one-dimensional behavior of the adiabatic dusty plasma could be govern by the following normalized fluid equation:

$$\frac{\partial n}{\partial t} + \frac{\partial}{\partial x}(nu) = Q_i - \nu_L n, \tag{2}$$

$$\frac{\partial p}{\partial t} + u\frac{\partial p}{\partial x} + \gamma_i p\frac{\partial u}{\partial x} - \frac{\gamma_i p(Q_i - \nu_L n)}{n} = 0, \tag{3}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = -\frac{\partial \phi}{\partial x} - \frac{\sigma_i}{n}\frac{\partial p}{\partial x} - \frac{(Q_i - \nu_L n)u}{n} - \nu_i u, \tag{4}$$

$$\frac{\partial^2 \phi}{\partial x^2} = \frac{1}{\delta_{ie}} n_e - n + 1 - \frac{1}{\delta_{ie}}, \tag{5}$$

where n (n_e) is the ion (electron) density normalized to n_{i0} (n_{e0}). Given that DIAWs are the ion acoustic wave (IAWs) in dusty plasma, the time scale t is in units of the ion plasma period $\omega_{pi}^{-1} = \sqrt{\varepsilon_0 m_i/(n_{i0}e^2)}$ and the space scale x is in units of ion Debye length $\lambda_i = \sqrt{\varepsilon_0 T_e/(n_{i0}e^2)}$. Here ε_0 is permittivity of vacuum and e is the electron charge. The velocity u is normalized by IAW speed $c_i = \sqrt{T_e/m_i}$. The electrostatic potential ϕ is normalized by e/T_e. The pressure p is normalized by $n_{i0}T_i$ and γ_i is the ion adiabatic index. The ion loss frequency ν_L and collision frequencies $\nu_i = \nu_{id} + \nu_{in}$ are normalized by ω_{pi}, with ν_{id} (ν_{in}) being the ion–dust (ion–neutral) collision frequencies. The ion creation term Q_i is normalized by $n_{i0}\omega_{pi}$. Notably, $\sigma_i = T_i/T_e$ and $\delta_{ie} = n_{i0}/n_{e0}$, where T_e and T_i are the electron temperatures and ion temperatures, respectively. The ion creation Q_i could be expanded as[25]

$$Q_i = \nu_L\left[1 + \frac{\Delta\sigma}{\sigma_0}\phi + \frac{1}{2\sigma_0}\left(\frac{d^2\sigma}{d\phi^2}\right)_0\phi^2 + \cdots\right], \tag{6}$$

where σ_0 and $\Delta\sigma$ represent the coefficients of the zeroth and first order terms, respectively, in the Taylor expansion of the ionization cross-section (σ) as a function of ϕ near $\phi = 0$. In general, the parameter $\Delta\sigma/\sigma_0$ indicates ionization cross section. The electron follows the Kappa distribution and the densities is expressed as[20]

$$n_e = 1 + B_1\phi + B_2\phi^2\cdots, \tag{7}$$

where

$$B_1 = \frac{\kappa - \frac{1}{2}}{\kappa - \frac{3}{2}}, \quad B_2 = \frac{(\kappa - \frac{1}{2})(\kappa + \frac{1}{2})}{2(\kappa - \frac{3}{2})^2}, \tag{8}$$

and κ is superthermal index. According to the reductive perturbation technique, the independent variables are stretched as

$$\xi = \sqrt{\varepsilon}(x - \lambda t), \quad \tau = \varepsilon^{3/2}t, \tag{9}$$

where ε represents an arbitrary small quantity and λ is the phase velocity of the DIAW. Then the dependent plasma variables n, p, u, and ϕ can be expanded as

$$f = f_0 + \varepsilon f_1 + \varepsilon^2 f_2, \tag{10}$$

where $f = n, u, p, \phi$ and $n_0 = p_0 = 1$, $u_0 = \phi_0 = 0$. Under actual experimental conditions,[24,25] one has $\nu_L \approx O(\varepsilon^{3/2})$ and $\nu_i \approx O(\varepsilon^{3/2})$. Substituting the perturbations into Eqs. (2)–(5), then equating terms with the lowest power of ε, one obtains

$$-\lambda\frac{\partial n_1}{\partial \xi} + \frac{\partial u_1}{\partial \xi} = 0, \tag{11}$$

$$-\lambda\frac{\partial p_1}{\partial\xi}+\gamma_{\rm i}\frac{\partial u_1}{\partial\xi}=0, \tag{12}$$

$$\sigma_{\rm i}\frac{\partial p_1}{\partial\xi}-\lambda\frac{\partial u_1}{\partial\xi}+\frac{\partial\phi_1}{\partial\xi}=0, \tag{13}$$

$$n_1-A_1\phi_1=0. \tag{14}$$

Equating terms with the next higher order in ε, from Eqs. (2)–(5), one reaches

$$\nu_{\rm L}n_1-\frac{\Delta\sigma}{\sigma_0}\nu_{\rm L}\phi_1+\frac{\partial n_1}{\partial\tau}+u_1\frac{\partial n_1}{\partial\xi}-\lambda\frac{\partial n_2}{\partial\xi}+n_1\frac{\partial u_1}{\partial\xi}+\frac{\partial u_2}{\partial\xi}=0, \tag{15}$$

$$\gamma_{\rm i}\nu_{\rm L}n_1-\frac{\Delta\sigma}{\sigma_0}\gamma_{\rm i}\nu_{\rm L}\phi_1+\frac{\partial p_1}{\partial\tau}-\lambda n_1\frac{\partial p_1}{\partial\xi}+u_1\frac{\partial p_1}{\partial\xi}-\lambda\frac{\partial p_2}{\partial\xi}+\gamma_{\rm i}n_1\frac{\partial u_1}{\partial\xi}+\gamma_{\rm i}p_1\frac{\partial u_1}{\partial\xi}+\gamma_{\rm i}\frac{\partial u_2}{\partial\xi}=0, \tag{16}$$

$$\nu_{\rm i}u_1+\frac{\partial u_1}{\partial\tau}+\sigma_{\rm i}\frac{\partial p_2}{\partial\xi}-\lambda n_1\frac{\partial u_1}{\partial\xi}+u_1\frac{\partial u_1}{\partial\xi}-\lambda\frac{\partial u_2}{\partial\xi}+n_1\frac{\partial\phi_1}{\partial\xi}+\frac{\partial\phi_2}{\partial\xi}=0, \tag{17}$$

$$n_2-A_2{\phi_1}^2-A_1\phi_2+\frac{\partial^2\phi_1}{\partial{\xi^2}}=0, \tag{18}$$

with $A_1=B_1\delta_{\rm ie}^{-1}$, $A_2=B_2\delta_{\rm ie}^{-1}$. Equations (11)–(14) give the phase velocity as

$$\lambda=\sqrt{\frac{1+\gamma_{\rm i}A_1\sigma_{\rm i}}{A_1}}. \tag{19}$$

Combining Eqs. (11)–(18) yields

$$\frac{\partial\phi_1}{\partial\tau}+\alpha\phi_1\frac{\partial\phi_1}{\partial\xi}+\beta\frac{\partial^3\phi_1}{\partial\xi^3}+\gamma\phi_1=0, \tag{20}$$

with the coefficients

$$\alpha=\frac{-2A_2+A_1^2(3+\gamma_{\rm i}(1+\gamma_{\rm i})A_1\sigma_{\rm i})}{2A_1^{3/2}\sqrt{1+\gamma_{\rm i}A_1\sigma_{\rm i}}}, \tag{21}$$

$$\beta=\frac{1}{2A_1^{3/2}\sqrt{1+\gamma_{\rm i}A_1\sigma_{\rm i}}}, \tag{22}$$

$$\gamma=\frac{1}{2}(\nu_{\rm L}+\nu_{\rm i})-\frac{\Delta\sigma}{2\sigma_0}A_1^{-1}\nu_{\rm L}. \tag{23}$$

Employing Tamang's method[28] and using the boundary conditions: $\phi_1=\frac{{\rm d}^2\phi_1}{{\rm d}\xi^2}=\frac{{\rm d}\phi_1}{{\rm d}\xi}=0$ when $\eta\to\pm\infty$, we can reach the following stationary solution of the damped K-dV equation:

$$\phi_1=\phi_{\rm m}(\tau){\rm sech}^2\left[\frac{\xi-U(\tau)\tau}{W(\tau)}\right], \tag{24}$$

where the wave velocity $U(\tau)$, the amplitude $\phi_{\rm m}$, and the width $W(\tau)$ are given by

$$U(\tau)=U_0\,{\rm e}^{-(4/3)\gamma\tau}, \tag{25}$$

$$\phi_{\rm m}(\tau)=\frac{3U_0}{\alpha}\,{\rm e}^{-(4/3)\gamma\tau}, \tag{26}$$

$$W(\tau)=\sqrt{\frac{4\beta\,{\rm e}^{(4/3)\gamma\tau}}{U_0}}. \tag{27}$$

Given that this analysis pertains to the study of small-amplitude DIASWs, the initial wave velocity U_0 is assumed to remain constant.

As specified above, the nonlinear excitations of DIASWs are characterized by the constituent coefficients described in the DKdV equation. Physically, these three coefficients refer to the strength of nonlinearity (α), dispersion (β), and damping (γ) effects, respectively, in the nonlinear excitations of DIASWs. From Eq. (26), it can be observed that the nonlinearity coefficients α is inversely proportional to the amplitude of the DIASW. From Eq. (27), the dispersion term β is proportionate to the width of the DIASW.

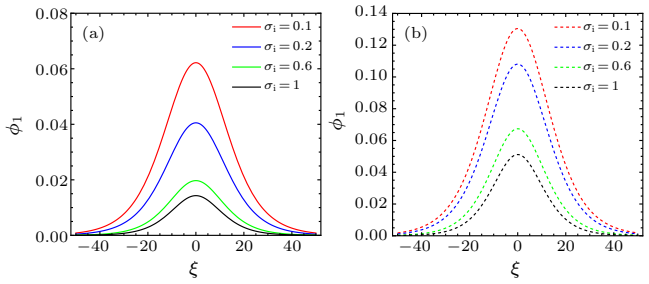


Fig. 1. Electrostatic potential profiles for distinct values of ion-to-electron temperature ratio $\sigma_{\rm i}$ [$\sigma_{\rm i}=0.1$ (red), $\sigma_{\rm i}=0.2$ (blue), $\sigma_{\rm i}=0.6$ (green), $\sigma_{\rm i}=1$ (black)] with (a) $\gamma_{\rm i}=3$ and (b) $\gamma_{\rm i}=1$. Other parameters are taken as $\delta_{\rm ie}=2$, $\kappa=4$, $\tau=0$, and $U_0=0.01$.

3. Result and discussion

In this section, the effect of ion-to-electron temperature ratio $\sigma_{\rm i}$, ion-to-electron density ratio $\delta_{\rm ie}$, ion adiabatic index $\gamma_{\rm i}$, superthermal electron parameter κ and other parameters on the DIASW solution of the DKdV equation are presented. Figure 1 shows the effect of the ion-to-electron temperature ratio $\sigma_{\rm i}$ on the DIASW. With the increase in the ion-to-electron temperature ratio $\sigma_{\rm i}$, the amplitude and width of DIASW decrease, as shown in Fig. 1. DIAWs are low frequency waves in which the driving force (the restoring force) is provided by the inertia (the thermal pressure) of the ion (electron) species.[38] The increase of ion-to-electron temperature ratio $\sigma_{\rm i}$ (the decrease of electron temperature) causes the decreases in the restoring force and consequently decreases the amplitude of the DIASW. The amplitude of the solitary wave decreases with the increasing ion adiabatic index $\gamma_{\rm i}$ as observed by comparing Fig. 1(a) with Fig. 1(b). The nonlinearity coefficient α increases with the increasing ion-to-electron temperature ratio $\sigma_{\rm i}$ and the ion adiabatic index $\gamma_{\rm i}$, as shown in Fig. 2(a). Figure 2(b) shows that the dispersive term β decreases with increasing the ion-to-electron temperature ratio $\sigma_{\rm i}$ and the ion adiabatic index $\gamma_{\rm i}$.

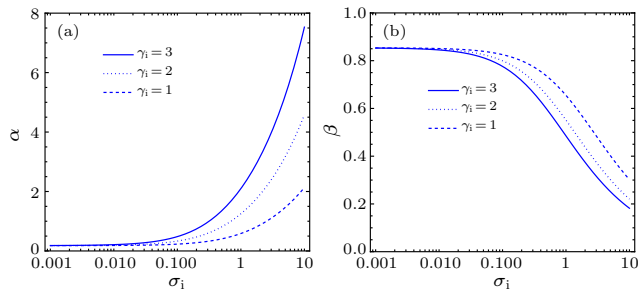


Fig. 2. (a) The nonlinearity coefficient α and (b) the dispersion term β versus σ_i for $\gamma_i = 3$ (curved line), $\gamma_i = 2$ (dotted line) and $\gamma_i = 1$ (dashed line). Other parameters are taken as $\delta_{ie} = 2$ and $\kappa = 4$.

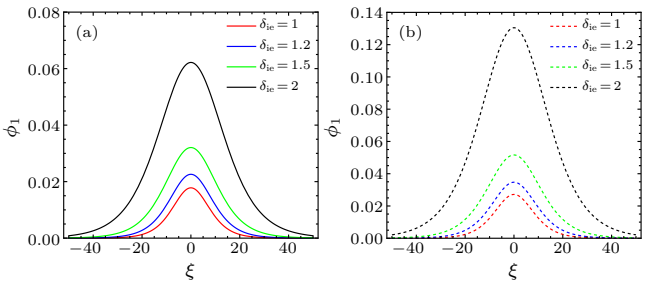


Fig. 3. Electrostatic potential profiles for distinct values of ion-to-electron density ratio δ_{ie} [$\delta_{ie} = 1$ (red), $\delta_{ie} = 1.2$ (blue), $\delta_{ie} = 1.5$ (green), $\delta_{ie} = 2$ (black)] with (a) $\gamma_i = 3$ and (b) $\gamma_i = 1$. Other parameters are taken as $\sigma_i = 1$, $\kappa = 4$, $\tau = 0$, and $U_0 = 0.01$.

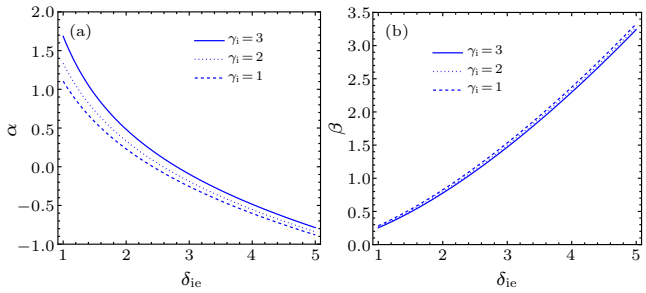


Fig. 4. (a) The nonlinearity coefficient α and (b) the dispersion term β versus δ_{ie} for $\gamma_i = 3$ (curved line), $\gamma_i = 2$ (dotted line) and $\gamma_i = 1$ (dashed line). Other parameters are taken as $\sigma_i = 1$ and $\kappa = 4$.

The effect of the ion-to-electron density ratio δ_{ie} on DIASW is depicted in Fig. 3. With the increase in the ion-to-electron density ratio δ_{ie}, the amplitude and width of DIASW increase, as shown in Fig. 3. The increase of ion density causes the increases in the driving force and consequently magnifies the amplitude of the DIASW. By comparing Fig. 3(a) with Fig. 3(b), the amplitude of the solitary wave decreases with increasing the ion adiabatic index γ_i. Figure 4(a) shows that the nonlinearity coefficient α decreases with increasing the ion-to-electron density ratio δ_{ie}, but increases with the increasing ion adiabatic index γ_i. It should be noted that the solitons solution of the DKdV equation (19) represents the rarefactive solitary wave when the nonlinearity coefficient $\alpha < 0$. There exists a rarefactive solitary wave (i.e., $\alpha < 0$) when the ion-to-electron density ratio δ_{ie} is large (i.e., $\delta_{ie} > 3$), as shown in Fig. 4(a). Figure 4(b) shows that the dispersive term β increases with the ion-to-electron density ratio δ_{ie} enhanced, while decreases slowly with increasing the ion adiabatic index γ_i.

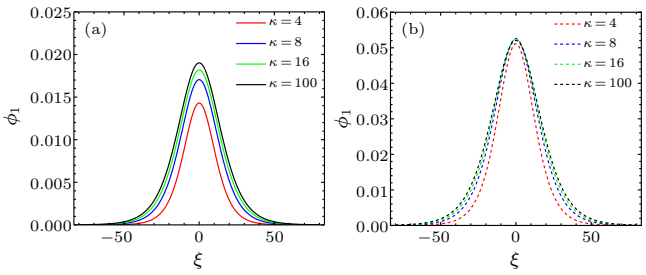


Fig. 5. Electrostatic potential profiles for distinct values of superthermal electrons parameter κ [$\kappa = 4$ (red), $\kappa = 8$ (blue), $\kappa = 16$ (green), $\kappa = 100$ (black)] with (a) $\gamma_i = 3$ and (b) $\gamma_i = 1$. Other parameters are taken as $\delta_{ie} = 2$, $\sigma_i = 1$, $\tau = 0$, and $U_0 = 0.01$.

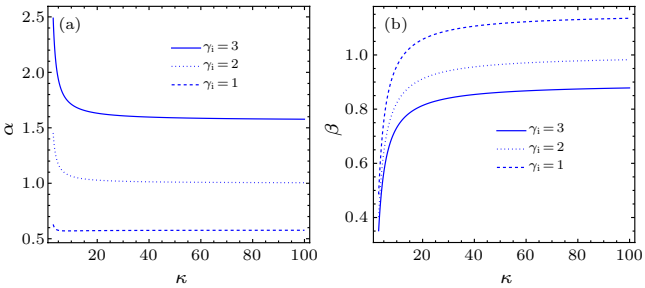


Fig. 6. (a) The nonlinearity coefficient α and (b) the dispersion term β versus κ for $\gamma_i = 3$ (curved line), $\gamma_i = 2$ (dotted line) and $\gamma_i = 1$ (dash line). Other parameters are taken as $\delta_{ie} = 2$ and $\sigma_i = 1$.

Figure 5 demonstrates the impact of the superthermal index κ on the basic features of DIASW. The amplitude and width of DIASW increase with the increase in superthermal index κ and both of them approach an asymptotic value, as shown in Fig. 5. The amplitude of the solitary wave decreases with increasing the ion adiabatic index γ_i as observed by comparing Fig. 5(a) with Fig. 5(b). Figure 6(a) shows that the nonlinearity coefficient α decreases and approaches an asymptotic value with increasing the superthermal index κ. It should be noted that Maxwell–Boltzmann distribution is recovered though at the limit of $\kappa \to \infty$.[16] With the increase in the ion adiabatic index γ_i, the nonlinearity coefficient α decreases. Figure 6(b) shows that the dispersive term β increases and approaches an asymptotic value with increasing the superthermal index κ. With increasing the ion adiabatic index γ_i, the dispersive term β decreases.

From Eqs. (26) and (27), it can be observed that the solitary waves become lower and wider with time when the damping term γ is positive, while become higher and narrower when the damping term γ is negative. Due to combination effects of ionization and collisions, the amplitude of the DIASW may damp or grow with time. Figure 7(a) shows that in the absence of ionization (i.e., $\nu_L = 0$), collisional effects lead to damping of the DIASW. In the absence of collisions (i.e., $\nu_i = 0$), ionization effects lead to growing of the DIASW. The results obtained from our investigation completely agree with Ghosh.[25] Specially, the solitary waves neither growth nor damping when the plasma parameters are located at the separate line ($\gamma = 0$) between two regions. By comparing Fig. 7(a) with Fig. 7(b), and Fig. 7(c) with Fig. 7(d), it can be observed that with the

increases in ion-to-electron density ratio δ_{ie}, superthermal index κ and ionization cross-section $\Delta\sigma/\sigma_0$, the domain for the solitary wave grow will expand, that is, the effect of ionization on DIASW enhances.

It is clearly seen that the amplitude of DIASW becomes lower or higher with increasing time due to the combined effects of collision and ionization, as shown in Fig. 8. For general plasma situations, the plasma parameters are $\sigma_i = 0.033$, $\delta_{ie} = 2.2$, $\Delta\sigma/\sigma_0 = 2$, $\nu_i = 0.155$, $\nu_L = 0.054$, $\kappa = 4$, and $U_0 = 0.01$.[20] The above plasma parameters are located in the damping ($\gamma > 0$) region of Fig. 7(a), so the amplitude of DIASW becomes lower with increasing time as shown in Fig. 8(a). The plasma parameters are located in the growth ($\gamma < 0$) region of Fig. 7(c) when $\kappa = 10$ while keeping other parameters unchanged, which leads to the amplitude of DIASW becoming higher with increasing time as shown in Fig. 8(c). Comparing Fig. 8(a) with Fig. 8(b) or Fig. 8(c) with Fig. 8(d), we can find that the amplitude of DIASW decreases with increasing the ion adiabatic index γ_i.

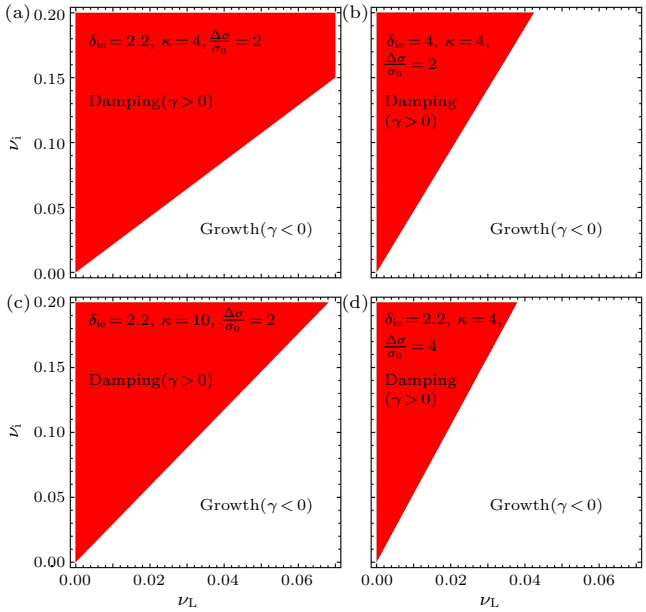


Fig. 7. The distribution diagram for the damping ($\gamma > 0$) or growth ($\gamma < 0$) of solitary waves on $\nu_L - \nu_i$ plane with (a) $\delta_{ie} = 2.2$, $\kappa = 4$, $\Delta\sigma/\sigma_0 = 2$; (b) $\delta_{ie} = 4$, $\kappa = 4$, $\Delta\sigma/\sigma_0 = 2$; (c) $\delta_{ie} = 2.2$, $\kappa = 10$, $\Delta\sigma/\sigma_0 = 2$; and (d) $\delta_{ie} = 2.2$, $\kappa = 4$, $\Delta\sigma/\sigma_0 = 4$.

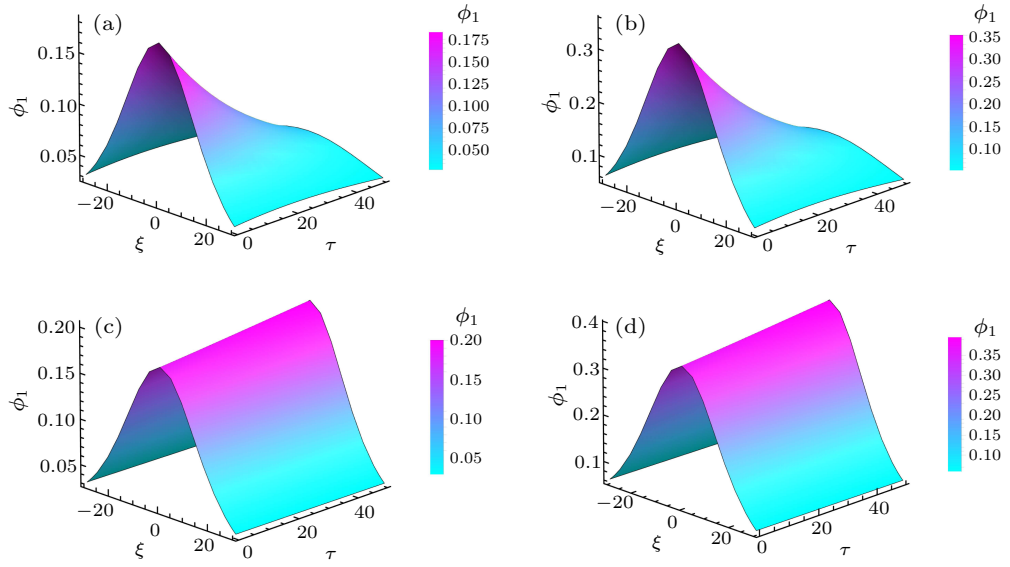


Fig. 8. Spatial and time evolution of the compressive DIASW for (a) $\gamma_i = 3$, $\kappa = 4$; (b) $\gamma_i = 1$, $\kappa = 4$; (c) $\gamma_i = 3$, $\kappa = 10$; and (d) $\gamma_i = 1$, $\kappa = 10$. Other parameters are taken as $\sigma_i = 0.033$, $\sigma = 0.033$, $\delta_{ie} = 2.2$, $\Delta\sigma/\sigma_0 = 2$, $\nu_i = 0.155$, $\nu_L = 0.054$, and $U_0 = 0.01$.

4. Summary

We have investigated the dynamics of DIASWs in a collisional dusty plasma consisting of adiabatic ions, superthermal electrons, and negatively charged static dust particles. Both the effects of ionization and ion loss have been taken into consideration. The reductive perturbation is employed to derive the damped Korteweg–de Vries (DKdV) equation. The effects of ion-to-electron temperature ratio σ_i, ion-to-electron density ratio δ_{ie}, ion adiabatic index γ_i, superthermal electrons parameter κ and other parameters on DIASWs are analyzed based on the DKdV equation. With the increase in the ion-to-electron temperature ratio σ_i (ion-to-electron density ratio δ_{ie}), the amplitude and width of the DIASW decrease (increase). The width and amplitude of the DIASW increase and approach an asymptotic value with the increase of superthermal index κ. With the ion adiabatic index γ_i increases, the nonlinearity coefficient α increases and the dispersive term β decreases. The ionization effect makes the solitary wave growing, while collisions reduce the growth rate and even lead to the damping. With the increase in ionization cross section $\Delta\sigma/\sigma_0$, ion-to-electron density ratio δ_{ie} and superthermal index κ, the effect of ionization on DIASW enhances. Considering the wide existence of nonlinear phenomena in dusty plasma, present investigation may be helpful for understanding the propagation behavior of solitary waves in nonequilibrium laboratory and space dusty plasmas environments, such as the Lunar iono-

sphere, earth noctilucent cloud, solar zodiacal dust cloud, and so on. The effect of magnetic field will be investigated in our future work due to the fact that magnetic field has a strong influence on ions and electrons in dust plasmas.

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