Arbitrary Amplitude Dust Acoustic Solitary Waves in Magnetized Two-Temperature Ions Plasma

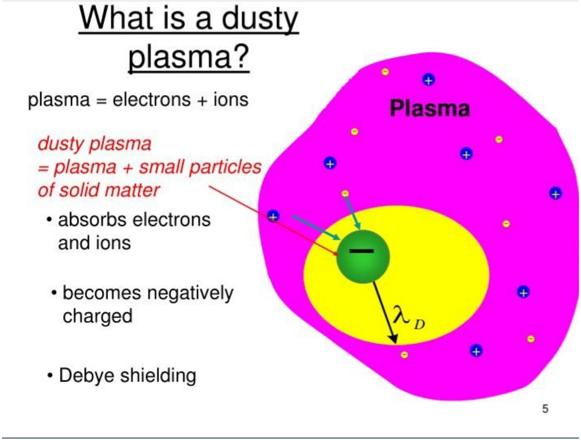
MPhil Scholar: Muazma Aisha
Supervisor: Dr. Rashid Ahmad
Reg.No: PH320202004

Department of physics
Kohat University of Science & Technology, Kohat, Pakistan

Outline

Dusty plasma

- Usual electron and ion plasma with a charged particle of micron- or sub-micron-sized particles



Dusty plasma occurrence

- Interstellar medium,
- asteroids zones,
- planetary rings,
- Earth's ionosphere and magnetosphere and laboratory environments.
- Microelectronic processing, rocket exhaust, dust in fusion devices

Dusty plasma with two temperatures ion

- two different temperature, hot and cold maxwellian distributions of ions
- such plasma investigated both experimentally and theoratically.
- properties of plasma with two temperature ions is studied in the magnetosphere zone.

Linear and non linear waves

- for growing small perturbations ((RPT) linear approximation)
- as amplitude grows larger non-perturbative approach should be used i-e Sagdeev's pseudo-potential method.
- Nonlinear waves are used in a variety of disciplines of physics, including fluids, atmospheric and astrophysics, and Bose-Einstein condensate, as well as LASER interactions with plasma.

Objectives of the research

1. The investigation of dispersion relation derived through linear analysis in two temperature ion dusty plasma.
2. The derivation of Sagdeev-potential through pseudo-potential method.
3. The study of two temperature ions effect on large amplitude DASWs

Abstract

- A *Hydrodynamics Model* is employed to investigate arbitrary amplitude DAWs in magnetized two different temperature ions plasma
- Homogeneous magnetic field is assumed to be directed along the z-axis i.e. $B = B_0 z$
- In the linear analysis, two branches of wave's propagation are found to occur in the oblique direction. The characteristics of large amplitude DASWs propagation in oblique direction are studied through energy balance equation, by applying a Sagdeev potential approach.

Model equations

$$\frac{\partial n_d}{\partial t} + \nabla \cdot (n_d \mathrm{v}_d) = 0, \tag{1}$$

$$\left(\frac{\partial}{\partial t} + \mathrm{v}_d \cdot \nabla\right) \mathrm{v}_d = \frac{e}{m_d} \nabla \phi - \frac{eB_0}{m_d c} \mathrm{v}_d \times \hat{z}. \tag{2}$$

$$n_{ic} = n_{ic0} e^{\frac{-e\phi}{k_B T_{ic}}} \tag{3}$$

$$n_{ih} = n_{ih0} e^{\frac{-e\phi}{k_B T_{ih}}} \tag{4}$$

And charge neutrality is defined as:

$$n_d \approx n_{ic} + n_{ih}. \tag{5}$$

The standard linear procedure consists of Fourier analyzing , by assuming small perturbations $\sim e^{i\left(k_x x - k_z z \omega t\right)}$. one obtains a dispersion relation given as:

$$\omega^2 = \frac{k^2}{k^2 + \alpha} \tag{6}$$

$$\omega^2 = \frac{\Omega^2(k^2+\alpha) + k^2 \pm \sqrt{\left(\Omega^2(k^2+\alpha)+k^2\right)^2 - 4(k^2+\alpha)k_z^2 + \Omega^2}}{2(k^2+\alpha)} \tag{7}$$

Where

$$\alpha = 2\delta_{ic}\delta_{Tic} + 2\delta_{ih}\delta_{Tih}$$

linear Dispersion relation

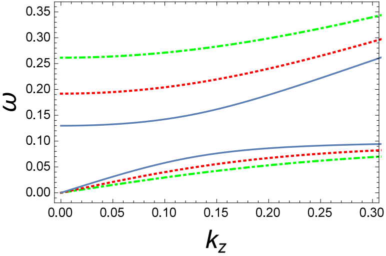


Figure: Plot showing normalized angular frequency ω versus parallel propagation vector k_z. The lower curves depict the acoustic, while the upper curve represent Langmuir like modes for three different values of the perpendicular component of the wave vector k_x, solid line $k_x = 0.1$, dotted line $k_x = 0.2$ and dotted-dashed line $k_x = 0.3$, while keeping $\Omega = 0.01$, $\delta_T = 0.01$ and $\delta_{ih} = 0.6$ are fixed.

linear Dispersion relation

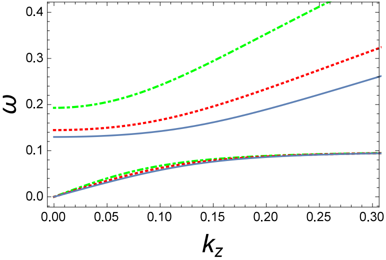


Figure: Plot showing normalized angular frequency ω versus parallel propagation vector k_z. The lower curves depict the acoustic, while the upper curve represent Langmuir like modes for three different values of the hot ions density ratio δ_{ih}, solid line $\delta_{ih} = 0.6$, dotted line $\delta_{ih} = 0.4$ and dotted-dashed line $\delta_{ih} = 0.2$, while keeping $\Omega = 0.01$, $\delta_T = 0.01$ and $k_x = 0.1$ are fixed.

linear Dispersion relation

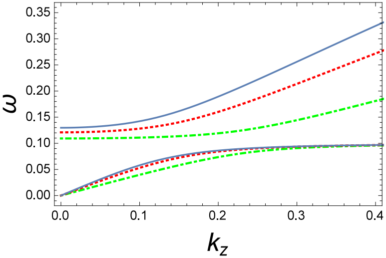


Figure: Plot showing normalized angular frequency ω versus parallel propagation vector k_z. The lower curves depict the acoustic, while the upper curve represent Langmuir like modes for three different values of the cold to holt ions temperature ratio δ_T, solid line $\delta_T = 0.01$, dotted line $\delta_T = 0.05$ and dotted-dashed line $\delta_T = 0.1$, while keeping $\Omega = 0.01$, $\delta_{ih} = 0.6$ and $k_x = 0.1$ are fixed.

linear Dispersion relation

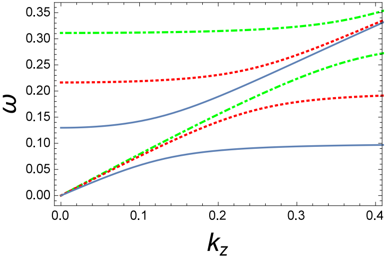


Figure: Plot showing normalized angular frequency ω versus parallel propagation vector k_z. The lower curves depict the acoustic, while the upper curve represent Langmuir like modes for three different values of the magnetic field via Ω δ_T, solid line $\Omega = 0.01$, dotted line $\Omega = 0.05$ and dotted-dashed line $\Omega = 0.1$, while keeping $\delta_T = 0.01$, $\delta_{ih} = 0.6$ and $k_x = 0.1$ are fixed.

Large amplitude electrostatic oblique solitary waves excitations

we introduce a moving variable $\xi = l_x x + l_z z - Mt$, where $M = \frac{V}{c_s}$ is the normalized pulse velocity (with V denoting the soliton speed). The parameters l_x and l_z denote the directional cosines along the x and z directions, i.e., $l_x = \frac{k_x}{k} = \sin\theta$ and $l_z = \frac{k_z}{k} = \cos\theta$ (*viz.*, $l_x^2 + l_z^2 = 1$). Assuming that all fluid variables in evolution Equations depend on ξ, one is led to a set of coupled ordinary differential equations in the co-moving co-ordinate ξ.

Large amplitude electrostatic oblique solitary waves excitations

The transformed equations read as:

$$-M\frac{dn_d}{d\xi}+l_x\frac{d\left(n_d v_{dx}\right)}{d\xi}+l_z\frac{d\left(n_d v_{dz}\right)}{d\xi})=0, \tag{8}$$

$$\left(-M+l_x v_{dx}+l_z v_{dz}\right)\frac{dv_{dx}}{d\xi} = l_x\frac{d\Phi}{d\xi}-\Omega v_{dy}, \tag{9}$$

$$\left(-M+l_x v_{dx}+l_z v_{dz}\right)\frac{dv_{dy}}{d\xi} = \Omega v_{dx}, \tag{10}$$

$$\left(-M+l_x v_{dx}+l_z v_{dz}\right)\frac{dv_{dz}}{d\xi} = l_z\frac{d\Phi}{d\xi}, \tag{11}$$

Large amplitude electrostatic oblique solitary waves excitations

we obtain a pseudo-energy-conservation condition in the form

$$\frac{1}{2}\left(\frac{d\Phi}{d\xi}\right)^2 + \mathrm{R}(\Phi, M, \Omega) = 0, \tag{12}$$

where

$$\mathrm{R}(\phi, M, \Omega) = \Omega^2 \frac{\psi_1(\Phi, M)}{\psi_2(\Phi, M)} \tag{13}$$

Large amplitude electrostatic oblique solitary waves excitations

$$\Psi_1(\Phi, M) = Z(\Phi) - \frac{l_z^2 z^2(\Phi)}{2M^2} + \frac{M^2}{n_d} - \frac{M^2}{2} - \frac{M^2}{2n_d^2} + l_z^2(1 + \frac{1}{n_d}) + \left(1 - 2l_z^2(\delta_{ic} + \delta_{ih}\delta_T)\right)\Phi$$

$$\Psi_2(\Phi, M) = \left(1 - \frac{M^2(2\delta_{ic}e^{-2\Phi} + 2\delta_{ih}\delta_T e^{-2\delta_T\Phi})}{(\delta_{ic}e^{-2\Phi} + \delta_{ih}e^{-2\delta_T\Phi})^3}\right)^2. \qquad (14)$$

Soliton existence conditions

$$\frac{d^2\Psi}{d\xi^2}\Big|_{\Phi=0} = \Omega^2 \frac{M^2 - M_1^2}{M^2\left(M^2 - M_2^2\right)} < 0 \tag{15}$$

with

$$M_1 = L_Z\left(2(\delta_{ic} + \delta_{ih}\delta_T))\right)^{-1/2} \tag{16}$$

and

$$M_2 = \left(2(\delta_{ic} + \delta_{ih}\delta_T)\right)^{-1/2} \tag{17}$$

$$M_1 < M < M_2 \tag{18}$$

for $l_z \neq 1$ i.e.,

$$l_z < \frac{M}{M_2} < 1. \tag{19}$$

M_1 and M_2 are lower and upper limits of the Mach number (M) respectively. Also, it is to be necessary to note here, that for $L_z = 1$ (i.e. at parallel propagation $\theta = 0$), (15) cannot be satisfied and the prescribed model breaks down due to coincide of the lower and upper limits of the Mach number(M) in such case no soliton solution possible.

Effect of Mach Number

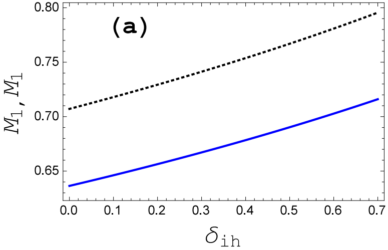


Figure: Plot shows the critical Mach number M_1 on top line and M_2 at the bottom line are depicted vs different plasma parameter, the hot ions density ratio δ_{ih} taking $\delta_T = 0.01$ and $l_z = 0.9$ for plot (a).

Effect of Mach Number

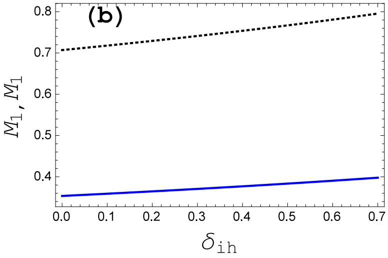


Figure: Plot shows the critical Mach number M_1 on top line and M_2 at the bottom line are depicted vs different plasma parameter the hot ions density ratio δ_{ih} taking $\delta_T = 0.01$ and $l_z = 0.5$ for (b)

Effect of Mach Number

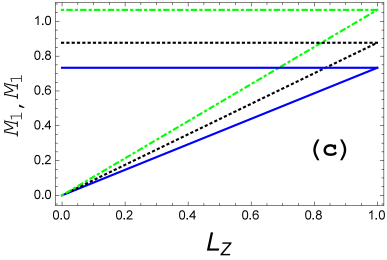


Figure: Plot shows the critical Mach number M_1 on top line and M_2 at the bottom line are depicted vs different plasma parameter, the obliqueness lz for three different values of δ_T for solid line $\delta_T = 0.01$ for dotted $\delta_T = 0.05$ and for dashed-dotted $\delta_T = 0.05$ while keeping $\delta_{ih} = 0.6$.

Effect of hot ions density (δ_{ih})

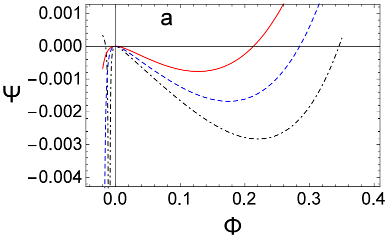


Figure: (a)The pseudopotential $\Psi_(\Phi)$ is plotted against Φ for three different values of $\delta_{ih} = 0.6$ for dashed-dotted line; $\delta_{ih} = 0.4$ for dashed line; and $\delta_{ih} = 0.2$ for solid line, keeping the fixed values of $\delta_T = .01$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$.

Effect of hot ions density (δ_{ih})

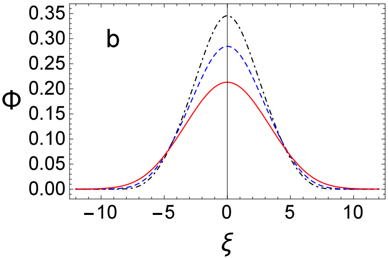


Figure: (b)The corresponding electrostatic potential (soliton) for three different values of $\delta_{ih} = 0.6$ for dashed-dotted line; $\delta_{ih} = 0.4$ for dashed line; and $\delta_{ih} = 0.2$ for solid line, keeping the fixed values of $\delta_T = .01$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$.

Effect of hot ions density (δ_{ih})

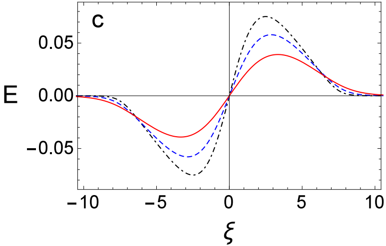


Figure: (c)The resulting electric field are depicted, for three different values of $\delta_{ih} = 0.6$ for dashed-dotted line; $\delta_{ih} = 0.4$ for dashed line; and $\delta_{ih} = 0.2$ for solid line, keeping the fixed values of $\delta_T = .01$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$.

Effect of temperature (δ_T)

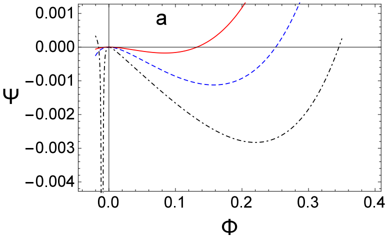


Figure: (a)The pseudopotential $\Psi_{(}\Phi)$ is plotted against Φ for three different values of $\delta_T = 0.01$ for dashed-dotted line; $\delta_T = 0.05$ for dashed line; and $\delta_T = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$.

.

Effect of temperature (δ_T)

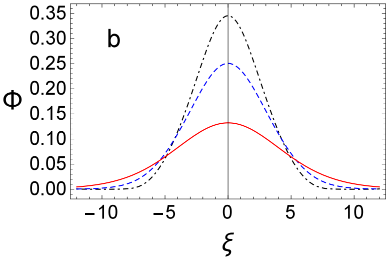


Figure: (b)The corresponding electrostatic potential (soliton) for three different values of $\delta_T = 0.01$ for dashed-dotted line; $\delta_T = 0.05$ for dashed line; and $\delta_T = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$.

Effect of temperature (δ_T)

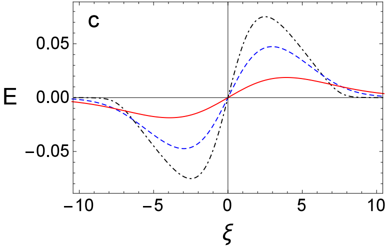


Figure: (c)The resulting electric field are depicted for three different values of $\delta_T = 0.01$ for dashed-dotted line; $\delta_T = 0.05$ for dashed line; and $\delta_T = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\Omega = 0.01$ and $M = 0.67$

Effect of magnetic field

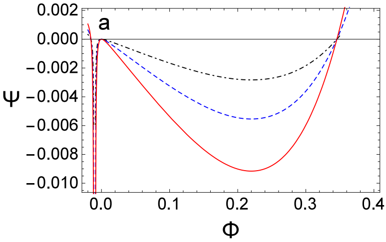


Figure: (a)The pseudopotential $\Psi_{(}\Phi)$ is plotted against Φ for three different values of $\Omega = 0.01$ for dashed-dotted line; $\Omega = 0.05$ for dashed line; and $\Omega = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\delta_T = 0.01$ and $M = 0.67$

Effect of magnetic field

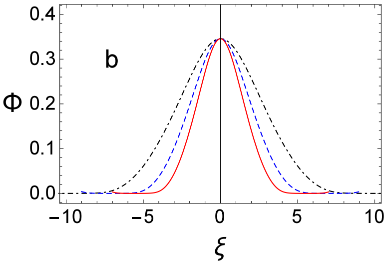


Figure: (b) The corresponding electrostatic potential (soliton) for three different values of $\Omega = 0.01$ for dashed-dotted line; $\Omega = 0.05$ for dashed line; and $\Omega = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\delta_T = 0.01$ and $M = 0.67$

Effect of magnetic field

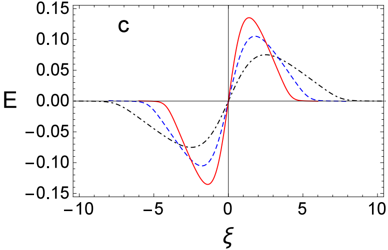


Figure: (c) The resulting electric field are depicted for three different values of $\Omega = 0.01$ for dashed-dotted line; $\Omega = 0.05$ for dashed line; and $\Omega = 0.1$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $l_z = 0.8$, $\delta_T = 0.01$ and $M = 0.67$

Effect of obliqueness l_z

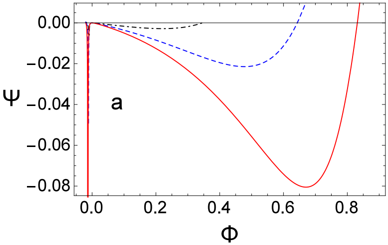


Figure: (a)The pseudopotential $\Psi_(\Phi)$ is plotted against Φ for three different values of $l_z = 0.8$ for dashed-dotted line; $l_z = 0.6$ for dashed line; and $l_z = 0.4$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $\Omega = 0.01$, $\delta_T = 0.01$ and $M = 0.67$.

Effect of obliqueness l_z

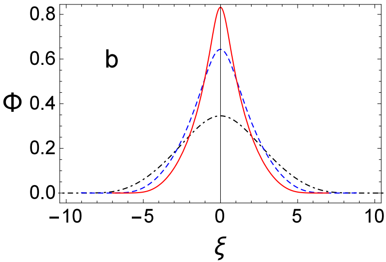


Figure: (b) The corresponding electrostatic potential (soliton) for three different values of $l_z = 0.8$ for dashed-dotted line; $l_z = 0.6$ for dashed line; and $l_z = 0.4$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $\Omega = 0.01$, $\delta_T = 0.01$ and $M = 0.67$.

Effect of obliqueness l_z

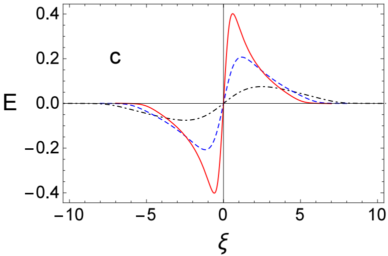


Figure: (c) The resulting electric field are depictedfor three different values of $l_z = 0.8$ for dashed-dotted line; $l_z = 0.6$ for dashed line; and $l_z = 0.4$ for solid line, keeping the fixed values of $\delta_{ih} = 0.6$, $\Omega = 0.01$, $\delta_T = 0.01$ and $M = 0.67$.

conclusion

- The value of M_1 reduced by reducing l_z i.e. (more oblique) which enhances interval for soliton existence region. The soliton existence region shrinks as we go from high value of l_z to low value.
- The amplitude and width of the soliton are effected by δ_{ih} , which decreases the depth of the Sagdeev potential well with increases δ_{ih} values. It is observed that by increasing δ_{ih} values amplitude increase width of soliton decrease and hence, solitary waves are more localized and steeper.
- It is also found that, both the amplitude and depth of the potential increase with an increase δ_T values, hence the structures with a greater value of δ_T within soliton existence domain are predicted to be shorter and spread out in width.