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THE NONLINEAR MAGNETOSONIC WAVES IN MAGNETIZED DENSE PLASMA FOR QUANTUM EFFECTS OF DEGENERATE ELECTRONS[†]

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The nonlinear magnetosonic solitons are investigated in magnetized dense plasma for quantum effects of degenerate electrons in this research work. After reviewing the basic introduction of quantum plasma, we described the nonlinear phenomenon of magnetosonic wave. The reductive perturbation technique is employed for low frequency nonlinear magnetosonic waves in magnetized quantum plasma. In this paper, we have derived the Korteweg-de Vries (KdV) equation of magnetosonic solitons in a magnetized quantum plasma with degenerate electrons having arbitrary electron temperature. It is observed that the propagation of magnetosonic solitons in a magnetized dense plasma with the quantum effects of degenerate electrons and Bohm diffraction. The quantum or degeneracy effects become relevant in plasmas when fermi temperature and thermodynamic temperatures of degenerate electrons have same order.
Keywords: Magnetosonic wave, Quantum Plasma, Korteweg-de Vries equation (KdV) equation.
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The study of quantum plasma has been growing interest during the last decade due to its enormous applications on large scale systems in compact astrophysical objects such as white dwarfs, neutron stars and pulsars containing dense plasmas and on short scale systems such as in semiconductors, quantum devices and on nanometer scales such as quantum wells, quantum dots, nano-tubes and spintronics. The quantum or degeneracy effects become relevant in plasmas when the de Broglie wavelength associated with charge carriers becomes of the order of the average inter-particle distance so that there is a significant overlap of the corresponding wave functions or the Fermi temperature is same as the temperature of the system.

Firstly, Haas [1] introduced the quantum hydrodynamic (QHD) model used for quantum corrections in plasma. Thereafter, the proposal of QMHD model explaining spin-1⁄2 effect of degenerate electrons for low-frequency waves in magnetized quantum plasmas was given by Marklund and Brodin [2]. In a quantum magnetoplasma, the quantum Bohm potential and electron spin-1⁄2 effects using the Sagdeev potential approach was studied for magnetosonic solitons [3]. In the system of QMHD, the electron spin-1⁄2 changes to the shape of the magnetosonic solitary waves due to the balance between the nonlinearity and quantum diffraction/ tunneling effects. Spin Alfv´en solitons were investigated in magnetized electron-positron plasmas [4] by deriving a modified KdV equation in the MHD limit. It was shown that the collective spin effects may influence the wave characteristics in a strongly magnetized quantum plasma.The QHD model can be generalized by adding the quantum statistical pressure term (the Fermi-Dirac distribution) and the quantum diffraction term (the Bohm potential) to the fluid model [5, 6].

The QHD was used to investigate the quantum magnetosonic waves and a deformed Korteweg-de Vries (KdV) equation was derived by Haas et al. [7]. In classical plasma, the KdV equation is well known for the small but limited amplitude of ionic sound wave [8], [9]. Both degenerate (without spin) and non-degenerate (with spin) quantum plasmas were studied respectively by using small amplitude limited perturbation scheme obliquely two-dimensional nonlinear magnetosonic waves [10 – 11]. Many authors have studied the linear and nonlinear low-frequency waves in quantum plasma such as ion acoustic waves, drift waves etc. [12 - 14].

It has been proved that by adding positrons to the plasma as usual, their collective behavior has changed considerably [15] - [18]. Plasma [29] smashing [18], [20] the early universe, the vital role of survival and electron-positron (E-P) have collective behavior. Although most of the astronomical environments can be considered by the EP plasma existent senses [21], [22], the EP plasma combination in nonrelativistic regimes is astronomical plasma in some aspects [20], [23]. Verheest et al. studied through a reductive disturbance analysis, large amplitude in electron-positron plasma studied solitary electromagnetic waves and received a modified Korteweg-de verse (mKdV) equation [24]. Using two fluid plasma samples, Kourakis et al. [25] the pair studied parallel wavelength packets in parallel magnetic plasma in pairs. With this approach, Esfandyari-Kalejahi et al. E-P-I is considered nonlinear propagation of amplitude collective electrostatic wave-packets in Plasma [26]. Esfandyari-Kalejahi et al. [27] Studied electrostatic waves which unmagnified collision pair modulation of nonlinear amplitude propagation in plasma. Furthermore, many researchers have examined solder tissue structures in magnetic plasma, which are derived from the Zakharov-Kuznetsov (ZK) equation in various media. For example, Kourakis et al. have studied Magnetic mixed pair-ion plasma molecular electrostatic reactions are equated with linear dissemination analysis and forming their dimensional solutions [28]. The spread of shear Alfven waves in a strongly magnetic e-P-I plasma has been investigated by U. et al. [29], and also in Quantum E-P-I plasma, solitary waves were examined [20]. In the presence of stable ions, in the presence of Mahmoud et al., QHD for

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disseminating nonlinear acoustic wave in dense magnetic e-p plasma, ZK has found the equation and found that the positron concentration decreases the wave dimension increases.

THEORETICAL FORMULATION

In order to study the nonlinear low frequency magnetosonic wave propagation, we take the set of dynamic equations for solving our problem. The set of quantum magnetohydrodynamic include the ion continuity equation and momentum equations as follows.

The ion continuity equation and for nondegenerate ions fluid are –

$$\frac{\partial n_i}{\partial t} + \nabla.(n_i u_i) = 0\,, \tag{1}$$

$$\frac{\partial u_i}{\partial t} + \left(u_i.\nabla\right) u_i = \frac{e}{m_i}\left(\vec{E} + u_i \times \vec{B}\right), \tag{2}$$

where u_i is ion fluid velocity, n_i is ionic number density and m_i is the ion mass.
The electron continuity equation and momentum equation for degenerate electrons are –

$$\frac{\partial n_e}{\partial t} + \nabla.(n_e u_e) = 0\,, \tag{3}$$

$$\frac{\partial u_e}{\partial t} + u_e.\nabla u_e = -\frac{e}{m_e}\left(\vec{E} + u_e \times \vec{B}\right) - \frac{\nabla P_e}{n_e m_e} + \frac{\alpha}{3}\frac{\hbar^2}{2m_e^{\,2}}\nabla\left(\frac{\nabla^2\sqrt{n_e}}{\sqrt{n_e}}\right), \tag{4}$$

where n_e is unperturbed electron number density, P_e is electron pressure and the term $\hbar^2$ arises due to electron tunneling through the Bohm potential. The numerical coefficient α is expressed as-

$$\alpha = \frac{Li_{\frac{3}{2}}(-e^{\beta\mu})Li_{-\frac{1}{2}}(-e^{\beta\mu})}{[Li_{\frac{1}{2}}(-e^{\beta\mu})]^2}\,. \tag{5}$$

Let z = exp($\beta\mu$). In the classical limit (z << 1) then α ≈ 1, whereas in the full degenerate limit (z >> 1) then α ≈ 1/3.
The Fermi-Dirac particle distribution function for electron is –

$$f\left(u,r,t\right) = \frac{A}{1 + e^{\beta(E-\mu)}}\,, \tag{6}$$

where $\beta=1/k_BT$, $E=m_ev^2/2$, $v=|u|$, k_B is the Boltzmann constant and μ is the chemical potential regarded as a slowly varying function of position **r** and time t.
The scalar pressure for equilibrium with zero drifts velocity as -

$$P = \frac{1}{3} m_e \int f u^2 d^3u\,. \tag{7}$$

This is equal to –

$$\mathrm{P} = \frac{n_e}{\beta}\frac{Li_{\frac{5}{2}}(-e^{\beta\mu})}{Li_{\frac{3}{2}}(-e^{\beta\mu})}\,. \tag{8}$$

The Maxwell's equations are -

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}\,, \tag{9}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}\,. \tag{10}$$

The current density is –

$$\vec{J} = e\left(n_i u_i - n_e u_e\right). \tag{11}$$

The equilibrium $n_{i0} = n_{e0} = n_0$ (say) has been defined. In order to study the obliquely propagating nonlinear magnetosonic wave propagating in x direction, i.e., $\nabla = (\partial_x, 0, 0)$ and electric field in a plane (xy) i.e., $\vec{E} = E_x\hat{x} + E_y\hat{y}$ .The linear dispersion relation for magnetosonic waves in a quantum plasma with arbitrary electron degeneracy is written as –

$$\omega^2 = \left(\upsilon_s^2 + \frac{\alpha}{12}\frac{\hbar^2}{m_i m_e}k^2\right)k^2 + \frac{k^2 u_a^2}{1 + k^2\lambda_e^2}, \tag{12}$$

where υ_s is ion acoustic speed and defined as –

$$\upsilon_s = \left(\frac{1}{\beta m_i}\frac{Li_{\frac{3}{2}}(-e^{\beta\mu_{(0)}})}{Li_{\frac{1}{2}}(-e^{\beta\mu_{(0)}})}\right)^{1/2}. \tag{13}$$

The dispersion relation is described as -

$$\omega^2 = \left(\upsilon_s^2 + \frac{\alpha}{12}\frac{\hbar^2}{m_i m_e}k^2\right)k^2 + \Omega_i\Omega_e. \tag{14}$$

The phase velocity is defined as –

$$\frac{\omega}{k} = \sqrt{\upsilon_s^2 + \upsilon_A^2}, \tag{15}$$

where υ_A is Alfven speed.

$$\omega^2 = \upsilon_s^2 k^2 + \frac{k^2 u_a^2}{1 + k^2\lambda_e^2}. \tag{16}$$

The dispersion relation for magnetosonic waves in quantum plasma with fully degenerate case can be written as –

$$\omega^2 = \left(\upsilon_s^2 + \frac{\hbar^2}{36 m_i m_e}k^2\right)k^2 + \frac{k^2 u_a^2}{1 + k^2\lambda_e^2}. \tag{17}$$

To explore the nonlinear structures, it is convenient to write governing equations in dimensionless and component form and it is convenient to use of normalized quantities. For this, we introduce the following dimensionless variables:

$$\bar{u}_{e,i} = u_{e,i}/\upsilon_s,\ \tilde{n}_{e,i} = n_{e,i}/n_0,\ \tilde{x}_{e,i} = \omega_p x/\upsilon_s,\ \tilde{t} = \omega_p t\quad \bar{\vec{E}} = e\vec{E}/m_i\upsilon_s\omega_p \text{ and } \bar{\vec{B}} = \vec{B}/B_0,$$

here

$$\bar{H} = \frac{\beta\hbar\omega_{pe}}{\sqrt{3}}\left(\frac{Li_{-1/2}(-e^{\beta\mu})}{Li_{3/2}(-e^{\beta\mu})}\right)^{1/2},$$

is the quantum diffraction dimensionless parameter and $\beta = k_B T$, k_B is the Boltzmann constant, T is the temperature and μ is the equilibrium chemical potential and γ = mi / me is ion electron mass ratio. The space (x) and time (t) variables are normalized by ion plasma frequency. Hereafter, we will be using these new variables and remove all the bars for simplicity of notations. The normalized ion continuity and momentum equations in the component form of dimensionless variables can be written as follows:

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial x}(n_i u_{ix}) = 0, \tag{18}$$

$$\frac{\partial u_{ix}}{\partial t} + u_{ix}\frac{\partial}{\partial x}u_{ix} = E_x + \Omega u_{iy}B, \tag{19}$$

$$\frac{\partial u_{iy}}{\partial t} + u_{iy}\frac{\partial}{\partial x}u_{iy} = E_y - \Omega u_{ix}B. \tag{20}$$

The normalized electron continuity and momentum equations in the component form of dimensionless variables can be written as follows:

$$\frac{\partial n_e}{\partial t}+\frac{\partial}{\partial x}(n_e u_{ex})=0\,, \tag{21}$$

$$\frac{\partial u_{ex}}{\partial t}+u_{ex}\frac{\partial}{\partial x}u_{ex}=-E_x-\Omega u_{ey}B-\frac{Li_{1/2}(-e^{\beta\mu_{(0)}})}{Li_{1/2}(-e^{\beta\mu_{(0)}})}\frac{\partial}{\partial x}n_e+\frac{\bar{H}^2}{2}\frac{\partial}{\partial x}\left[\frac{1}{\sqrt{n_e}}\frac{\partial^2}{\partial x^2}\sqrt{n_e}\right], \tag{22}$$

$$\frac{\partial u_{iy}}{\partial t}+u_{iy}\frac{\partial}{\partial x}u_{iy}=E_y-\Omega u_{ix}B\,. \tag{23}$$

The component form of Faraday's law –

$$\frac{\partial\vec{E}}{\partial x}=-\Omega\frac{\partial\vec{B}}{\partial t}\,. \tag{24}$$

The components form of Ampere's law -

$$0=n_i u_{ix}-n_e u_{ex}\,, \tag{25}$$

$$\Omega\frac{\partial\vec{B}}{\partial x}=\frac{\upsilon_s^2}{c^2}\left(n_e u_{ey}-n_i u_{iy}\right), \tag{26}$$

where $\Omega = \omega_{ci}/\omega_{pi}$ has been defined as normalized parameter of ion cyclotron and ion plasma frequency ratio. Where $\omega_{ci} = eB_0/m_i$ is the ion cyclotron frequency and $\omega_{pi}=\sqrt{\frac{n_0 e^2}{\varepsilon_0 m_i}}$ is the ion plasma frequency respectively.

DERIVATION OF KDV EQUATION FOR MAGNETOSONIC WAVES

Now, we derive the Korteweg-de Vries equation from (18)-(26) by employing the reductive perturbation technique and the stretched coordinates –

$$\delta=\varepsilon^{1/2}(x-v_p t) \text{ and } \tau=\varepsilon^{3/2}t, \tag{27}$$

where ε is a smallness parameter proportional to the amplitude of the perturbation and v_p is the phase velocity of wave.

We can expand the variables $n_{e(i)}$, $u_{e(i)}$, E, B and μ in a power series of ε as –

$$n_{e(i)}=1+\varepsilon n_{e(i)}^{(1)}+\varepsilon^2 n_{e(i)}^{(2)}+\ldots\,, \tag{28}$$

$$u_{e(i)x}=0+\varepsilon u_{e(i)x}^{(1)}+\varepsilon^2 u_{e(i)x}^{(2)}+\ldots\,, \tag{29}$$

$$u_{e(i)y}=\varepsilon^{3/2}u_{e(i)y}^{(1)}+\varepsilon^{5/2}u_{e(i)y}^{(2)}+\ldots\,, \tag{30}$$

$$E_x=\varepsilon^{3/2}E_x^{(1)}+\varepsilon^{5/2}E_x^{(2)}+\ldots\,, \tag{31}$$

$$B=1+\varepsilon B_z^{(1)}+\varepsilon^2 B_z^{(2)}+\ldots\,, \tag{32}$$

$$\mu=\varepsilon^{(1)}\mu+\varepsilon^2\mu^{(2)}+\ldots\,. \tag{33}$$

Now collecting the lowest order ($\varepsilon^{3/2}$) terms from ion continuity and momentum equations of components form (18) to (20) give –

$$-v_p \frac{\partial n_i^{(1)}}{\partial \delta} + \frac{\partial u_{ix}^{(1)}}{\partial \delta} = 0 \,, \tag{34}$$

$$-v_p \frac{\partial u_{ix}^{(1)}}{\partial \delta} = E_x^{(1)} + \Omega u_{iy}^{(1)} \,, \tag{35}$$

$$E_y^{(1)} = \Omega u_{ix}^{(1)} \,. \tag{36}$$

Now collecting the lowest order ($\varepsilon^{3/2}$) terms from electron continuity and momentum equations of components form (21) to (23) give –

$$-v_p \frac{\partial n_e^{(1)}}{\partial \delta} + \frac{\partial u_{ex}^{(1)}}{\partial \delta} = 0 \,, \tag{37}$$

$$-v_p \frac{\partial u_{ex}^{(1)}}{\partial \delta} = dE_x^{(1)} + d\Omega u_{ey}^{(1)} + d\frac{\partial n_e^{(1)}}{\partial \delta} \,, \tag{38}$$

$$E_y^{(1)} = \Omega u_{ex}^{(1)} \,. \tag{39}$$

The lowest order ($\varepsilon^{3/2}$) terms from component form of Faraday's law (24) –

$$\frac{\partial E_y^{(1)}}{\partial \delta} = v_p \Omega \frac{\partial B_z^{(1)}}{\partial t} \,. \tag{40}$$

The lowest order ($\varepsilon^{3/2}$) terms from components form of Ampere's law (25-26) -

$$0 = u_{ix}^{(1)} - u_{ex}^{(1)} \,, \tag{41}$$

$$\Omega \frac{\partial B_z^{(1)}}{\partial \delta} = \frac{\upsilon_s^2}{c^2}\left(u_{ey}^{(1)} - u_{iy}^{(1)}\right) . \tag{42}$$

Now, using (34) – (42) we have –

$$v_p = \pm\sqrt{1+\left(\frac{\upsilon_a}{\upsilon_s}\right)^2} \,. \tag{43}$$

Now collecting the next higher order (ε) terms can be written as following -

$$v_p \frac{\partial n_i^{(2)}}{\partial \delta} - \frac{\partial u_{ix}^{(2)}}{\partial \delta} = \frac{\partial n_i^{(1)}}{\partial \tau} + \frac{\partial}{\partial \delta}\left(n_i^{(1)} u_{ix}^{(1)}\right) , \tag{44}$$

$$v_p \frac{\partial n_e^{(2)}}{\partial \delta} - \frac{\partial u_{ex}^{(2)}}{\partial \delta} = \frac{\partial n_e^{(1)}}{\partial \tau} + \frac{\partial}{\partial \delta}\left(n_e^{(1)} u_{ex}^{(1)}\right) , \tag{45}$$

$$v_p \frac{\partial u_{ix}^{(2)}}{\partial \delta} + E_x^{(2)} + \Omega u_{iy}^{(2)} = \frac{\partial u_{ix}^{(1)}}{\partial \tau} + u_{ix}^{(1)} \frac{\partial u_{ix}^{(1)}}{\partial \delta} - \Omega u_{iy}^{(1)} B_z^{(1)} \,, \tag{46}$$

$$E_y^{(2)} - \Omega u_{ix}^{(2)} = -v_p \frac{\partial u_{iy}^{(1)}}{\partial \delta} + \Omega u_{ix}^{(1)} B_z^{(1)} \,, \tag{47}$$

$$v_p \frac{\partial u_{ex}^{(2)}}{\partial \delta} - dE_x^{(2)} - d\Omega u_{ey}^{(2)} - d\frac{\partial n_{ex}^{(2)}}{\partial \delta} = \frac{\partial u_{ex}^{(1)}}{\partial \tau} + u_{ex}^{(1)} \frac{\partial u_{ex}^{(1)}}{\partial \delta} + d\Omega u_{ey}^{(1)} B_z^{(1)} - d\alpha n_e^{(1)} \frac{\partial n_e^{(1)}}{\partial \delta} - d\frac{H^2}{4}\frac{\partial^3 n_e^{(1)}}{\partial \delta^3} \,, \tag{48}$$

$$dE_y{}^{(2)} - d\Omega u_{ex}{}^{(2)} = v_p \frac{\partial u_{ey}{}^{(1)}}{\partial \delta} + d\Omega u_{ex}{}^{(1)} B_z{}^{(1)}, \tag{49}$$

$$\frac{\partial E_y{}^{(2)}}{\partial \delta} - \Omega v_p \frac{\partial B_z{}^{(2)}}{\partial \delta} = -\Omega \frac{\partial B_z{}^{(1)}}{\partial \tau}, \tag{50}$$

$$u_{ix}{}^{(2)} - u_{ex}{}^{(2)} = (n_e{}^{(1)} - n_i{}^{(1)}) u_x{}^{(1)}, \tag{51}$$

$$\frac{\upsilon_s^2}{c^2}(u_{iy}{}^{(2)} - u_{ey}{}^{(2)}) + \Omega \frac{\partial B_z{}^{(2)}}{\partial \delta} = \frac{\upsilon_s^2}{c^2}(n_e{}^{(1)} u_{ey}{}^{(1)} - n_i{}^{(1)} u_{iy}{}^{(1)}). \tag{52}$$

In order to study the nonlinear magnetosonic wave propagation characteristics we using this equation $u_{ey}{}^{(1)} = -du_{iy}{}^{(1)}$ and other variables can be expressed in terms of $u_{ex}{}^{(1)}$ as followings-

$$u_{ey}{}^{(1)} = -du_{iy}{}^{(1)}, \tag{53}$$

$$u_{ex}{}^{(1)} = u_{ix}{}^{(1)}, \tag{54}$$

$$n_e{}^{(1)} = n_i{}^{(1)} = \frac{u_{ex}{}^{(1)}}{v_p}, \tag{55}$$

$$B_z{}^{(1)} = \frac{u_{ex}{}^{(1)}}{v_p}, \tag{56}$$

$$E_x{}^{(1)} = -\frac{1}{v_p d}(v_p d + 1)\frac{\partial u_{ex}{}^{(1)}}{\partial \delta} = -v_p \frac{\partial u_{ex}{}^{(1)}}{\partial \delta}, \tag{57}$$

$$u_{iy}{}^{(1)} = \frac{1}{\Omega v_p d}\frac{\partial u_{ex}{}^{(1)}}{\partial \delta}, \tag{58}$$

$$u_{ey}{}^{(1)} = \frac{1}{\Omega v_p}(v_p^2 - 1)\frac{\partial u_{ex}{}^{(1)}}{\partial \delta}. \tag{59}$$

Now, using above equation and eliminating $n_{e(i)}$, u_i, E and B we obtain –

$$\frac{\partial \psi}{\partial \tau} + A_1 \psi \frac{\partial \psi}{\partial \delta} + A_2 \frac{\partial^3 \psi}{\partial \delta^3} = 0. \tag{60}$$

Equation (60) is the Korteweg-de Vries (KdV) equation of the nonlinear magnetosonic wave in magnetized quantum plasma in terms of $u_{ex}{}^{(1)} = \psi$. Where the nonlinear coefficient A_1 and the dispersion coefficients A_2 are given by –

$$\left.\begin{aligned} A_1 &= \frac{1}{2}\left(3 - \frac{\alpha}{v_p^2}\right) \\ A_2 &= \frac{1}{2v_p}\left(1 - \frac{H^2}{4}\right) \end{aligned}\right\}. \tag{61}$$

The solution of the Korteweg-de Vries (KdV) equation is found by transforming the independent variables X and τ to -

$$K = \delta - C_0\tau,\ \tau = \tau, \tag{62}$$

where, C_0 is a constant velocity normalized by c.

Therefore, the solution of the Korteweg-de Vries (KdV) equation is –

$$\psi = \psi_m \operatorname{sech}^2\left(\frac{K}{\Delta}\right). \tag{63}$$

In order to get the existence of solitons structures, it is necessary to apply the boundary condition on wave. The exact solution of KdV is not possible because this equation is not exactly integral solution. However, a particular solution of KdV is possible. The boundary condition is –

$$\psi \to 0, \frac{d\psi}{dK} \to 0, \frac{d^2\psi}{dK^2} \to 0 at K \to \infty,$$

where ψ_m is the amplitude and $\Delta = 1/\alpha$ is the width of magnetosonic soliton is given by –

$$\left.\begin{aligned} \psi_m &= \frac{3C_0}{A_1} \\ \Delta &= \sqrt{\frac{4A_2}{C_0}} \end{aligned}\right\}. \tag{64}$$

RESULT AND DISCUSSION

1. The theory of magnetosonic waves can be applied to all degeneracy of electrons. However, here the Fermi temperature and thermodynamic temperatures have same order and strong interactions between charge carriers. The quantum diffraction parameter depends on electron thermal temperatures as shown in Figure 1. It can be seen from the figure that quantum diffraction parameter attains large value for cold plasma.

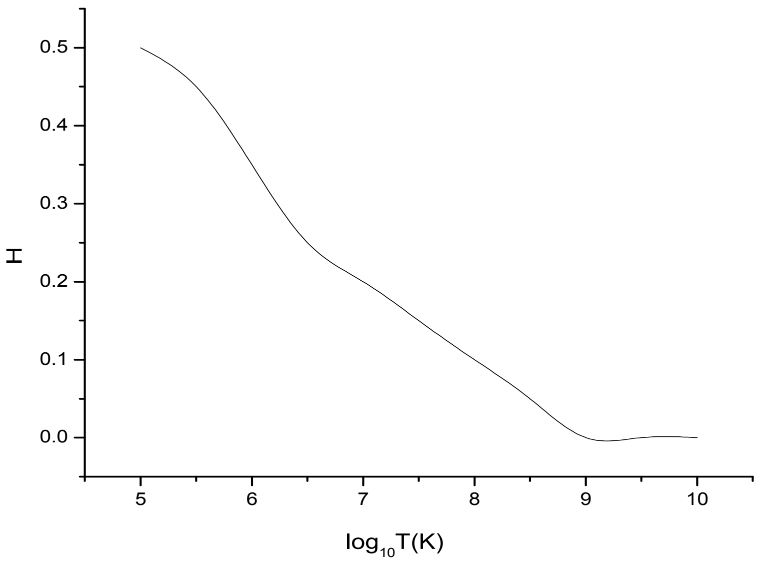

Figure 1. Variation of Quantum diffraction parameter H with temperature

2. Variation of Nonlinear dispersive coefficient A_2 as a function of temperature for magnetosonic waves is shown in Figure 2.

(a) The rarefactive magnetosonic solitons structures are formed only when velocity of nonlinear structure $C_0 < 0$ and nonlinear coefficient A_1 remains positive and nonlinear dispersive coefficient $A_2 < 0$ for electron temperature $T > 10^6$K. The speed of the nonlinear rarefactive soliton will be less than the phase speed of the magnetosonic waves.

(b) But the compressive magnetosonic solitons structures are formed when velocity of nonlinear structure $C_0 > 0$ and nonlinear coefficient A_1 remains positive and nonlinear dispersive coefficient $A_2 > 0$ for electron temperature $T < 10^6$K and it moves with a speed greater than the speed of the magnetosonic waves in the plasma with arbitrary degeneracy of electrons. The formation of magnetosonic dip structures in the higher temperature region is decreased with the increase of the magnetic field intensity.

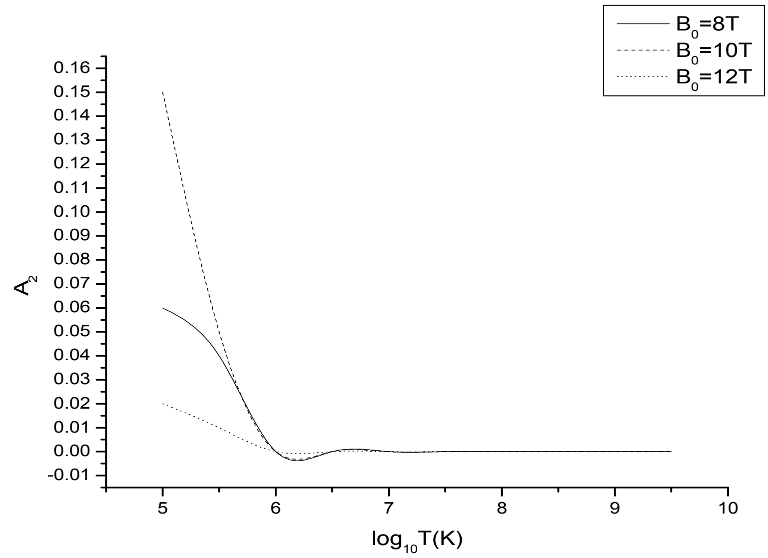

Figure 2. Nonlinear dispersive coefficient A_2 as a function of temperature

3. The variation of $\Omega = \omega_{ci}/\omega_{pi}$ as normalized parameter of ion cyclotron and ion plasma frequency ratio with different values of temperature as shown in Figure 3. It can be seen from the figure that the value of Ω decreases with increase in electron thermal temperature as well as magnetic field intensity.

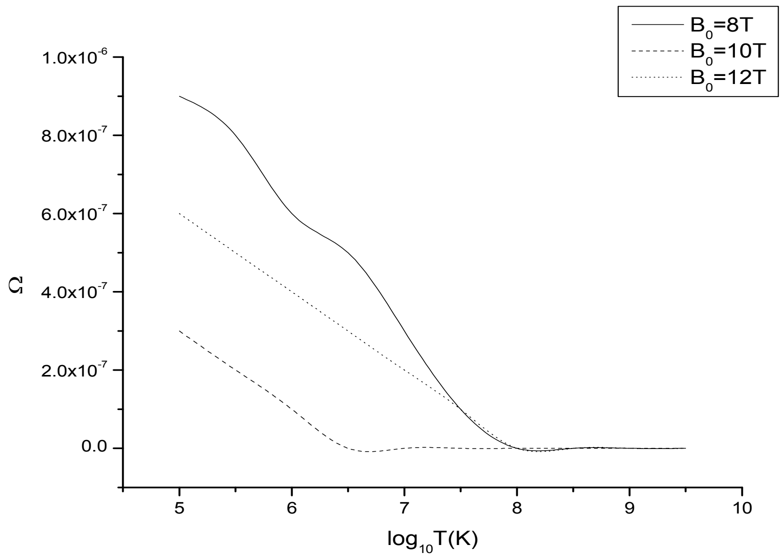

Figure 3. The ratio Ω of ion cyclotron to ion plasma frequency as a function of temperature

CONCLUSION

The weakly nonlinear propagation of magnetosonic soliton in magnetized dense plasma has been analyzed with the quantum effects of degenerate electrons, pressure degeneracy and Bohm diffraction. The reductive perturbation theory was used to derive Korteweg-de Vries (KdV) equation for the propagation of quantum magnetosonic waves in magnetized dense plasma. In weakly nonlinear limits, condition of shock wave has been discussed. Finally, we observed that this result relevant in plasma when fermi temperature and thermodynamic temperatures have same order.

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Declaration of interests

- The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

The first draft of the manuscript was written by [Neelam Rani]. All authors read and approved the final manuscript.

Availability of data and material

Authors have cited the data.

Compliance with ethical standards

- The manuscript has not submitted to other journal for simultaneous consideration.
- The submitted work is original and has not been published elsewhere.

Consent to participate

All authors agreed with the content and that all gave consent to submit the article.

Consent for Publication

All authors whose names appear on the submission have approved the content to be published.

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НЕЛІНІЙНІ МАГНІТОЗВУКОВІ ХВИЛІ В НАМАГНІЧЕНІЙ ЩІЛЬНОЇ ПЛАЗМІ ДЛЯ КВАНТОВИХ ЕФЕКТІВ ВИРОЖЕНИХ ЕЛЕКТРОнів

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У цій роботі досліджуються нелінійні магнітозвукові солітони в намагніченій щільній плазмі для квантових ефектів вироджених електронів. Ознайомившись з основним впровадженням квантової плазми, ми описали нелінійне явище магнітозвукової хвилі. Використовується метод відновного збурення для низькочастотних нелінійних магнітозвукових хвиль у намагніченій квантовій плазмі. У цій роботі ми вивели рівняння Кортевега-де Фріза (KdV) магнітозвукових солітонів у намагніченій квантовій плазмі з виродженими електронами, що мають довільну електронну температуру. Спостерігається, поширення магнітозвукових солітонів у намагніченій щільній плазмі з квантовими ефектами вироджених електронів і дифракції Бома. Квантові або ефекти виродження стають актуальними в плазмі, коли температура Фермі і термодинамічна температура вироджених електронів мають однаковий порядок.

Ключові слова: магнітозвукова хвиля, квантова плазма, рівняння Кортевега-де Фріза (КдВ).