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Exchange Corrections to Dispersion Properties of Lower Hybrid Wave in Ultra-Relativistic Degenerate Plasma

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Abstract: *The propagation characteristics of lower hybrid waves are studied in electron-ion degenerate plasma with exchange effect in non-relativistic, relativistic and ultra-relativistic regime. It is found that the combined effect of Bohm force and exchange correlation potential significantly alters the dispersion properties of lower hybrid waves. The analytical and numerical results explicitly show the influence of Bohm force, exchange correlation potential, relativistic velocities of electrons and kinetic pressure of ions on the frequency of the lower hybrid wave. Present work should be of relevance for the dense astrophysical environments like white dwarfs and for laboratory fusion plasma experiments.*
Keywords – *Ultra-relativistic plasma, lower hybrid waves, degenerate plasma, exchange correlation potential, laboratory fusion plasma experiments, tokomak's*

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I. Introduction

In high densities and low temperature plasma, when the de-Broglie wavelength of the particles becomes comparable to the average inter-particle distance, the quantum effects cannot be ignored. The dispersion properties of plasma waves in quantum plasmas are being studied in last few decades [1-3]. Study of electron and ion waves in such plasmas provides important insights about instabilities in various laboratory, space and astrophysical objects such as white dwarfs, pulsar magnetosphere, neutron star etc. [4-8]. Several authors have studied the propagation characteristics of electromagnetic waves in quantum plasma [9-14] incorporating Bohm force. In addition to this, degeneracy appears in the system involving some novel phenomena like exchange correlation potential [8, 15 and 16]. One of the simplest quantum systems exhibiting both diffraction and exchange effects is a fixed impurity in an ideal Fermi gas of electrons. The electron exchange and correlation effects embody a short-range electric potential which depends only on the number density of the Fermi particles. It has been observed that the electron exchange-correlation effects become significant for high density and low temperature plasmas such as in the ultra-small electronic devices [12]. Thus, the combine influence of both the dispersion effects and exchange potential can significantly affects the dynamics of waves in plasmas. In this regard many authors have studied different waves and instabilities in plasma considering combined influence of exchange potential and Bohm force. Ref. [20] have investigated the dispersion characteristics of extraordinary wave in electron-positron plasma with the inclusion of both the exchange potential and Bohm force and found the significant influence of both these parameters in affecting the dynamics of extraordinary waves. The instability of the upper-hybrid waves in semiconductor quantum magnetoplasma is investigated by [12] considering Bohm force, exchange potential and the quantum statistical pressure of the degenerate electrons. The Jeans instability of quantum dusty plasma with exchange effects is studied by [15]. Further, [21] have investigated stimulated scattering instabilities of circularly polarized electromagnetic waves carrying orbital angular momentum with the effect of exchange potential in dense quantum plasmas with degenerate electrons and non-degenerate ions. All these studies signify that wherever quantum effects are prominent the exchange effect can no longer be ignored. Thus, it is important to study exchange effect along with Bohm force in degenerate plasma systems.

An electron has continuous motion around the position it occupies. This motion exerts pressure on the surrounding medium, exactly as the thermal velocity of the molecules of a gas exerts its pressure. This pressure is called the electron degeneracy pressure (the electron pressure P is defined as the momentum transfer per unit area by the electrons). When electrons become degenerate then pressure is measured in terms of Fermi temperature T_{Fe} which depends on the particle density in the system [22]. But when the electrons are moving with relativistic or ultra-relativistic speed this degeneracy pressure gets modified [23, 24]. Ref. [25] has presented the equation of state for dense astrophysical plasmas systems having degenerate electrons. In the limiting cases, the equation of state for nonrelativistic degenerate electrons is defined as $p_{Fe} \sim n_e^{5/3}$ while for relativistic / ultra-relativistic degenerate electrons are given as $p_{Fe} \sim n_e^{4/3}$.

Further, the investigation regarding the electron acceleration and the magnetic reconnection phenomena (via. lower hybrid plasma waves) in laboratory, space, and astrophysical plasmas is widely studied by many researchers [26, 27]. Reconnection is fundamental process responsible for heating and accelerating plasma in solar flares, coronas around white dwarfs, neutron stars, and black holes, and in tokomak's [26]. Lower hybrid waves are important in space [28] and fusion plasmas [26, 29 and 30]. The lower hybrid waves are electrostatic waves that propagate almost perpendicular to the magnetic field and whose frequency lies in the vicinity of the lower-hybrid resonance frequency $\omega_L = \sqrt{\omega_c \Omega_c}$ (where Ω_c and ω_c are the ion and electron gyro frequencies, respectively). These waves are simultaneously in resonance with both the magnetized electrons and un-magnetized ions. The lower hybrid waves can provide the necessary electron acceleration that leads to plasma heating mechanism. The experiments on lower hybrid waves require strongly magnetized plasma. Since these waves are with a large k vector across the magnetic field which makes them attractive for radio-frequency heating of fusion plasmas. Thus, due to wide applications of electrostatic lower hybrid wave in various astrophysical and laboratory situations [26-30] in this letter, we have investigated the instability of the lower hybrid waves in electron-ion quantum magneto plasma taking into account the quantum Bohm force and exchange-correlation potential of electrons. The obtained dispersion relation is discussed considering three different regimes i.e., non-relativistic, relativistic and ultra-relativistic regime respectively. The present investigation is done using quantum hydrodynamic (QHD) model [8, 12 and 15]. This QHD model deals with the behavior of macroscopic quantities like density and current. The model has the advantage of mathematical efficiency and can be derived using Wigner-Poisson model [31].

The manuscript is organized as follows: In section 2 the basic QHD set of equations governing the dynamics of electron-ion quantum plasmas is presented. In section 3 linearized perturbation equations of the system along with the dispersion of lower hybrid waves for the three different cases (non-relativistic, relativistic and ultra-relativistic) is derived. In section 4, graphical discussion is presented which shows the contribution of exchange potential, magnetic field and Bohm force on the propagation characteristics of lower hybrid wave in magnetized plasmas. Finally in section 5, a brief discussion of the present work and summary is presented.

II. Model Equations For Degenerate Plasma System

We first consider the set of QHD equations [8, 12, 15] for degenerate plasma system consisting of electron and ion species. The dynamics of electrons and ions is governed by the ion continuity and momentum equations

$$\frac{\partial}{\partial t} n_e + n_e \nabla . \vec{v}_e = 0 \tag{1}$$

$$m_e n_e \frac{\partial}{\partial t} \vec{v}_e = q_e n_e \left(\vec{E} + \frac{1}{c} \left[\vec{v}_e, \vec{B} \right] \right) - \nabla P_e - \frac{\hbar^2}{4 m_e} \nabla \left(\nabla^2 n_e \right) - V_{exc} \nabla n_e \tag{2}$$

$$V_{e,xc} = -0.985 \frac{n_e^{1/3} e^2}{\varepsilon} \left[1 + \frac{0.034}{a_{Be}^{*} n_e^{1/3}} \ln \left(1 + 18.37 a_{Be}^{*} n_e^{1/3} \right) \right] \tag{3}$$

$$\frac{\partial}{\partial t} n_i + n_i \nabla . \vec{v}_i = 0 \tag{4}$$

$$m_i n_i \frac{\partial}{\partial t} \vec{v}_i = q_i n_i \left(\vec{E} + \frac{1}{c} \left[\vec{v}_i, \vec{B} \right] \right) - \nabla P_{ti} \tag{5}$$

where $n_{e,i}$, $\vec{v}_{e,i}$, $m_{e,i}$ and $q_{e,i}$ represents the number density, fluid velocity, mass and charge of species (e=electrons and i=ions) respectively. Equation (1) and (2) are the continuity and momentum equations for electrons in which P_e is the electron degeneracy pressure. Equation (3) shows the expression for exchange correlation potential [20] where ε is the dielectric constant of material and $a_{Be}^{*} = \varepsilon \hbar^2 / m q_e^2$ is the effective Bohr atomic radius of the species. Further, (4) and (5) describes the set of continuity and momentum equations respectively for non-degenerate ions. The ion thermal pressure is given via. equation of state i.e., $P_{ti} = k_B T_i n_i$ here T_i is temperature of ions and k_B is Boltzmann constant. The above equations (1) - (5) describe the governing set of equations to study electrostatic lower hybrid waves in degenerate magneto plasma. Now we would like to comment on the validity range of our model. The model is valid in the dense astrophysical region like outer regions of white dwarf, core of neutron star, pulsar magnetosphere (with temperature $T \approx 10^5 - 10^7 K$, magnetic field strength $B \approx 10^5 - 10^{10} T$ and unperturbed number density $n_0 \approx 10^{29} - 10^{39} m^{-3}$) [32] etc.; whereas the ions are non-relativistic and non-degenerate. The ions can be treated as cold fluid as their Fermi energy $\left(\hbar^2/2m_i\right)\left(3\pi^2\right)^{2/3} n_i^{2/3}$ is smaller than that of electrons [32].

III. Linearized Perturbation Equations And Dispersion Relation

Now in order to investigate the behavior of lower hybrid waves we make the following perturbation expansion for the fundamental quantities $n, \vec{v}, \vec{B}$ and $\vec{E}$ from their equilibrium values. The perturbation in these physical quantities can be ruled according to,

$$n = n_0 + n_1,\ \vec{v} = \vec{v}_0 + \vec{v}_1,\ \vec{B} = \vec{B}_0 + \vec{B}_1,\ \vec{E} = \vec{E}_0 + \vec{E}_1,\ P = P_0 + P_1 \tag{6}$$

where the subscript "1" denotes the perturbed part and subscript "0" denotes an unperturbed part. At equilibrium $\vec{v}_0$, $\vec{E}_0 = 0$. Therefore, using (6) the linearized set of equations can be given as

$$\frac{\partial}{\partial t} n_{e1} + n_{e0} \nabla . \vec{v}_{e1} = 0 \tag{7}$$

$$m_e n_{e0} \frac{\partial}{\partial t} \vec{v}_{e1} = q_e n_{e0} \left(\vec{E}_1 + \frac{1}{c} \left[\vec{v}_{e1}, \vec{B}_0 \right] \right) - \nabla P_{e1} - \frac{\hbar^2}{4m_e} \nabla \left(\nabla^2 n_{e1} \right) - V_{exc} \nabla n_{e1} \tag{8}$$

$$V_{e,xc} = -0.985 \frac{n_{e1}^{1/3} e^2}{\varepsilon} \left[1 + \frac{0.034}{a_{Be}^* n_{e0}^{1/3}} \ln \left(1 + 18.37 a_{Be}^* n_{e0}^{1/3} \right) \right] \tag{9}$$

$$\frac{\partial}{\partial t} n_{i1} + n_{i0} \nabla . \vec{v}_{i1} = 0 \tag{10}$$

$$m_i n_{i0} \frac{\partial}{\partial t} \vec{v}_{i1} = q_i n_{i0} \left(\vec{E}_1 + \frac{1}{c} \left[\vec{v}_{i1}, \vec{B}_0 \right] \right) - \nabla P_{ti1} \tag{11}$$

Now let the solution of the system of equations (7) - (11) be of the form $\exp\left[ik_x \hat{x} - i\omega t\right]$, where ω is the frequency of perturbation and k_x is the x-component of perturbed wave vector. Here we restrict ourselves to $\vec{E} = E_x \hat{x}$ and $\vec{B}_0 = B_0 \hat{z}$. To demonstrate the combine influence of Bohm force and exchange potential in our theoretical framework, we have considered following cases-

1.1. Non-relativistic plasma

In the present subsection we have considered the simplest case, here we assume that the electrons are non-relativistic and degenerate with exchange effects. The equation of state for non-relativistic degenerate electrons [25, 32] is given as

$$P_e = \frac{2}{5} n_e E_{Fe} \tag{12}$$

where $E_{Fe} = k_B T_{Fe} = \left(\hbar^2/2m\right)\left(3\pi^2\right)^{2/3} n^{2/3}$, therefore we get the expression for non-relativistic electron degeneracy pressure as $P_e = \hbar n_e^{1/3} \left(\hbar n_e^{1/3} / m_e \right) n_e$ which is same as mentioned by [1]. Now solving the linearized equations of motion (7)-(11) in terms of electron and ion densities and applying the quasi-neutrality condition $n_{i1} \approx n_{e1}$ one can get the following dispersion relation

$$\omega^2 = \omega_c \Omega_c + k^2 \left(1 + \frac{m_i}{m_e} \right)^{-1} \left[v_{fe}^2 - \frac{\hbar^2 k^2}{4m_e^2} - \frac{V_{j,exc}}{m_e} \right] + \left(1 + \frac{m_e}{m_i} \right)^{-1} k^2 v_{ti}^2 \tag{13}$$

for the lower hybrid waves in a non-relativistic degenerate plasma with exchange effects. It is worth mentioning that the quantum Bohm force and exchange potential decreases the Fermi velocity of electrons and hence decrease the frequency of growth rate ω while the ion thermal increases it. It is also clear that the lower hybrid frequency i.e. $\omega_L = \sqrt{\omega_c \Omega_c}$ gets modified due to these effects. The lower hybrid frequency ω_L is increased due to the quantum effects by the factor $k^2 \left\{1 + \left(m_i/m_e\right)\right\}^{-1} \left\{v_{fe}^2 - \left(\hbar^2 k^2/4m_e^2\right) - \left(V_{j,exc}/m_e\right)\right\} + \left\{1 + \left(m_e/m_i\right)\right\}^{-1} k^2 v_{ti}^2$.

To study the system numerically we have taken here the parameters of white dwarfs. In non-relativistic regime

we choose $n_i \sim n_e \sim 10^{32} - 10^{35}\,/\,\mathrm{m}^3$, $T_i \le 10^8 K$, $T_e \le 10^9 K$ and $B_0 \sim 10^2 - 10^5 T$ [32]. The Fermi velocity of non-relativistic electrons is estimated as $V_{fe} = 1.0444 \times 10^8\,\mathrm{m/sec}$ and thermal velocity of ions is $V_{ti} = 0.9 \times 10^6\, m/\sec$. The lower hybrid frequency is estimated as:
$\omega_L = 1.87 \times 10^{12}\,/\sec\left(\text{for } B = 10^\wedge 4T\right)$ and $\omega_L = 1.87 \times 10^{10}\,/\sec\left(\text{for } B = 10^\wedge 2T\right)$.

1.2. Relativistic and ultra-relativistic plasma

The expression for the degeneracy pressure of electrons with relativistic effects [24, 32] is given as

$$P_C = \frac{\pi}{3h^3} m_e^4 c^5 \left[\xi_C \left(2\xi_C^2 - 3\right)\left(1 - \xi_C^2\right)^{1/2} + 3\,\mathrm{Sinh}^{-1}\left(\xi_C\right) \right] \tag{14}$$

where $\xi_C = p_c e / m_e c$ in which $p_c = \left(3h^3 n_e / 8\pi\right)^{1/3}$ represents the momentum of electron on the Fermi surface [32]. Now on applying the limit $\xi_C \ll 1$[32], relation (12) is recovered from (14) for non-relativistic electrons. In ultra-relativistic limit [24] $\xi_C \gg 1$, the degeneracy pressure of ultra-relativistic electrons is given as $P_{\mathrm{Ultra}} = \left(\left(3\pi^2\right)^{1/3}/4\right)\hbar c n_e^{4/3}$, but for the case when electrons are relativistic, the relativistic electron pressure is taken as $P_{\mathrm{Rel}} = \hbar n_e^{1/3} c n_e$ [22-24]. Thus, it is clear that in going from nonrelativistic to relativistic regime the pressure dependence on density gets change [25]. The dispersion relation of lower hybrid wave for relativistic/ ultra-relativistic quantum plasma with exchange effects is given as

$$\omega^2 = \omega_c \Omega_c + k^2 \left(1 + \frac{m_i}{m_e}\right)^{-1} \left[V_{\mathrm{Rel./Ultra.}}^2 - \frac{\hbar^2 k^2}{4m_e^2} - \frac{V_{j,exc}}{m_e} \right] + \left(1 + \frac{m_e}{m_i}\right)^{-1} k^2 v_{ti}^2 \tag{15}$$

where $V_{\mathrm{Rel./Ultra.}}^2$ denotes the velocity of relativistic/ultra-relativistic electrons whose value is given as $V_{\mathrm{Rel.}}^2 = \left(4\hbar c/3m_e\right) n_{0e}^{1/3}$ and $V_{\mathrm{Ultra.}}^2 = \left(\hbar c/m_e\right) n_{0e}^{1/3}$. For relativistic and ultra-relativistic case the density range can be chosen as $n_i \sim n_e \sim 10^{36} - 10^{38}\,/\,\mathrm{m}^3$ and $n_i \sim n_e \sim 10^{39}\,/\,\mathrm{m}^3$ respectively while the magnetic field is same for the white dwarf star i.e., $B_0 \sim 10^2 - 10^5 T$ [32]. It is found that the relativistic effect dominates the lower hybrid frequency as relativistic and ultra-relativistic velocities are $V_{\mathrm{Rel.}}^2 = 5.1653 \times V_{Fe}^2$ and $V_{\mathrm{Ultra.}}^2 = 14.14594 \times V_{Fe}^2$ respectively. It is clear that these velocities get increased due to increase in momentum of electrons via. relativistic motion.

Further, the value of exchange parameter $\alpha = V_{e,xc}/m_e$ is simplified as [20]

$$\alpha = -\frac{\left(3\pi^2\right)^{2/3} H^2}{3} \left(0.985 + \frac{0.616}{1 + 1.9/H^2}\right) V_{Fe}^2 \approx \left(3\pi^2\right)^{2/3} V_{Fe}^2 H^2 / 3$$

where H is the quantum parameter which is given as $H = \left(\hbar \omega_{pe} / m_e V_{Fe}^2\right)$.

IV. Graphical Results And Discussion

Now in this section we have analyzed dispersion relation (13) and (15) numerically to visualize the role of exchange potential, Bohm force and degeneracy pressure on the dispersion properties of lower hybrid wave. The dispersion relation (13) and (15) can be rewrite into dimensionless form as

$$\omega^{*2} - \omega_c^* - M^* \left[k^{*2} \left(V^{*2} - \alpha_{exc}^{*2}\right) - H^{*2} k^{*4} \right] - k^{*2} = 0 \tag{16}$$

where the following dimensionless quantities are used

$$\omega^* = \frac{\omega}{\Omega_c},\; k^* = \frac{k v_{ti}}{\Omega_c},\; H^{*2} = \frac{\hbar^2 \Omega_c^2}{4m_e^2 v_{ti}^4},\; \alpha_{exc}^{*2} = \frac{\alpha_{exc}}{m_e v_{ti}^2},\; M^* = \frac{m_e}{m_i} \tag{17}$$

Equation (16) is the normalized dispersion relation of modified lower hybrid wave. It is to be mentioned that in (16) the influence of exchange correlation potential is mediated through the term proportional to α_{exc}^{*2}. The correction due to quantum Bohm force is mediated through H^{*2}. While the corrections due to relativistic and non-relativistic effects is given via V^{*2} in which we have used $V^* = V_{\mathrm{Fe}}/v_{ti}$ for non-relativistic case and $V^* = V_{\mathrm{Rel.}}/v_{ti}$ for relativistic and $V^* = V_{\mathrm{Ultra.}}/v_{ti}$ for ultra-relativistic case. The value of normalized parameters can be chosen in a range as $H = 0.0 - 0.4$, $\alpha_{exc}^{*} = 0.0 - 0.6$, $V^{*} = 0.0 - 0.4$ for non-relativistic case; $V^{*} = 0.5 - 0.7$ for relativistic case; and $V^{*} = 1.0 - 1.4$ for ultra-relativistic case. It follows from (16) that in long wavelength regime i.e., when $k^{*} \ll 1$, the quantum properties have no significant effect over the plasma dynamics. Whereas, for short wavelength oscillations i.e., when $k^{*} \gg 1$, the quantum effects may be comparable to or even dominant over the exchange effect. However, in dense plasma environments the degeneracy pressure may dominate over the exchange as well as diffraction effects.

Figures 1-3 are plotted to show the influence of exchange correlation potential, Bohm force, electron gyro frequency, Fermi pressure, relativistic and ultra-relativistic effects of electrons on the dispersion characteristics of lower hybrid waves.

In Fig. 1 the growth rate of lower hybrid wave ω^{*} is plotted against the normalized wave number k^{*} in the presence and absence of exchange effect (using (13)). In Fig. 1 the solid line and dashed line represents the presence of exchange effect when $\alpha_{exc}^{*} = 0.5$ and $\alpha_{exc}^{*} = 0.3$ respectively. While the dotted line shows the absence of exchange corrections. From figure it is clear that the presence of exchange parameter decreases the frequency of lower hybrid wave while the absence of exchange parameter increases it.

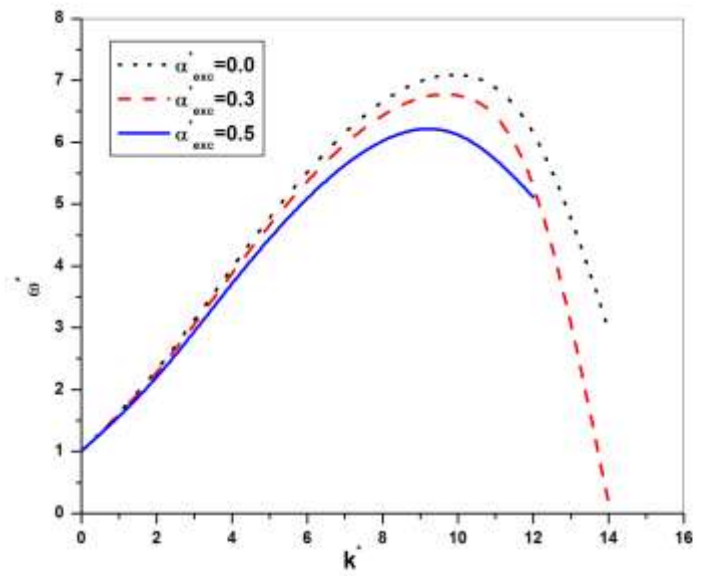

Fig. 1.

Further Fig. 2 shows that, how the electron gyro frequency and quantum parameter greatly influence the characteristics of lower hybrid wave. In Fig. 2 the dotted line corresponds to $\omega_c^{*} = 1.0$, $H^{*} = 0.2$, dashed line represents $\omega_c^{*} = 1.0$, $H^{*} = 0.3$, and solid line corresponds to $\omega_c^{*} = 2.0$, $H^{*} = 0.2$. Following conclusions can be drawn from Fig. 2

- If we compare the dotted and dashed line it shows that the increment in quantum parameter significantly decreases the frequency of lower hybrid wave and also changes the threshold of wave number.
- Further the comparison of dotted and solid line shows the influence of magnetic field on the growth rate of lower hybrid wave. It is concluded that the effect of ω_c^{*} is to increase the frequency of lower hybrid wave.

Thus, is clear that both the parameter $\left(\omega_c^{*} \text{ and } H^{*}\right)$ has significant influence on the growth rate of the system and affects the threshold wave number as well.

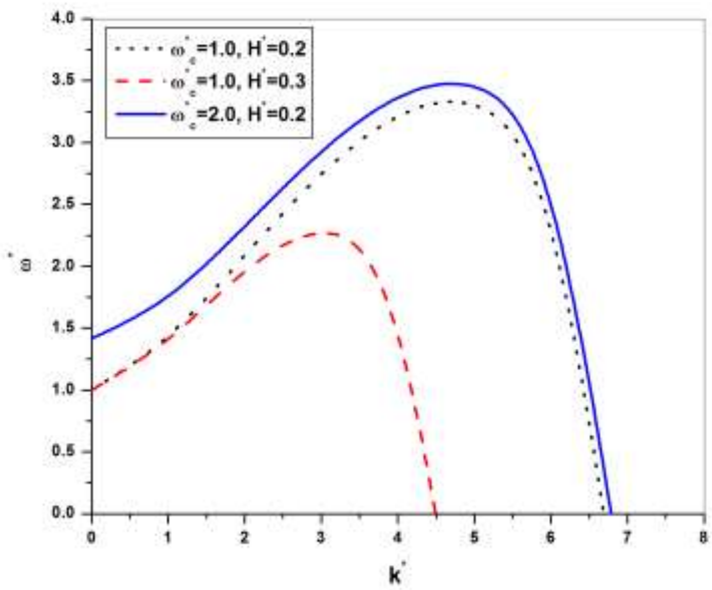

Fig. 2.

Further, it is quite interesting to study the individual role of non-relativistic, relativistic and ultra-relativistic effects of electrons in affecting the characteristics of lower hybrid wave. For this purpose we have plotted Fig. 3 that represents a comparison for non-relativistic (dotted line), relativistic (dashed line) and ultra-relativistic (solid line) regimes. It is found that in ultra-relativistic regime the phase velocity of lower-hybrid wave enhances abruptly as compared to that in relativistic and non-relativistic regime. Therefore, the relativistic and ultra-relativistic electrons of the system are significantly responsible for the frequent propagation of lower-hybrid waves in degenerate plasmas.

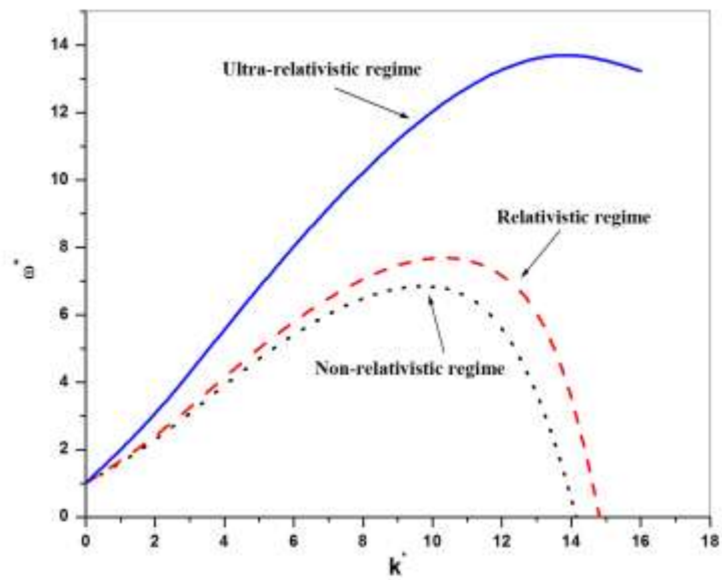

Fig. 3.

V. Summary

To summarize, we have investigated the role of exchange potential, magnetic field, degeneracy pressure and quantum Bohm force on the propagation characteristics of lower hybrid wave in relativistic quantum plasma system. In deriving the dispersion relation, we have considered the special case, where the electron-ion plasma is quasi-neutral. It is concluded that the relativistic effects significantly modify both the plasma current density and degenerate pressure and thus introduces correction terms in the dispersion relation, which in turn give rise to a new lower hybrid mode. Therefore, when the number density of electron is of the order $10^{36}/m^3$ as well as the external magnetic field is strong, the relativistic regime for this kind of plasma can no longer be ignored. But when the number density of electron is of the order $10^{39}/m^3$ plasma state enters into the ultra-relativistic regime. Thus, the obtained dispersion relation seems to be useful in understanding the propagation characteristics of lower hybrid wave in ultra-relativistic quantum plasma such as those found in dense astrophysical environments and laboratory fusion experiments.

References

[1] P. Sharma and R. K. Chhajlani, Phys. Plasmas 21, 2014,032101.
[2] A. E. Kalejahi, M. A. Moghanjoughi and E. Saberian, (2011) arXiv:1101.2740v1.
[3] S. Khan, Astrophys. Space Sci. 340, 2012,71–76.
[4] K. N. Mukta, M. S. Zobaer, N. Royand A. A. Mamun, J. Plasma Physics 81, 2015,905810326.
[5] H. Ren, Z. Wu and P. K. Chu, Phys. Plasmas 14, 2007, 062102.
[6] M. Yamada, Y. Ren, H. Ji, J. Breslau, S. Gerhardt, R. Kulsrud and A. Kuritsyn, Phys.Plasmas 13, 2006, 052119.
[7] P. Sharma and R. K. Chhajlani, Phys. Plasmas 21, 2014, 072104.
[8] R. Maroof, A. Mushtaq, and A. Qamar, Phys. Plasmas 23, 2016, 013704.
[9] F. Haas, Phys. Plasmas 10, 2003, 10.
[10] M. Marklund, G. Brodin, L. Stenflo and C.S. Liu arXiv:0712.3145v22008.
[11] W. Masood and B. Eliasson, Phys. Plasmas 18, 2011, 034503.
[12] M. Jamil, A. Rasheed, Ch. Rozina, W. M. Moslem and M. Salimullah, Phys. Plasmas 21,2014,020704.
[13] P. K. Shuklaand L. Stenflo, J. Plasma Physics 74(6), 2008, 719–723.
[14] Kyung-Sub Kim, Eun-Hwa Kim, Dong-Hun Lee and Kihong Kim, Phys. Plasmas 12, 2005,052903.
[15] M. Jamil, A. Rasheed, Ch. Rozina, Y. D. Jung and M. Salimullah, Phys. Plasmas 22, 2015, 082113.
[16] M. Shahmansouri, Phys. Plasmas 22, 2015, 092106.
[17] P.K. Shukla, Phys. letters A, 369, 2007, 312-314.
[18] A.P. Misra, G. Brodin, M. Marklund and P.K. Shukla, J. Plasmas Phys. 76, 2010, 857-864.
[19] F.A. Asenjo, Phys. Lett. A 376, 2012, 2496.
[20] M. Shahmansouri and A. P. Misra, Phys. Plasmas 23, 2016, 072105.
[21] P K Shukla, B Eliasson and LennartStenflo, Physical Review E 86, 2012, 016403.
[22] S. Hussain, S. Mahmood, and Aman-ur- Rehman, Phys. Plasmas21, 2014, 112901.
[23] P K Shukla, D.A. Mendis and S.I. Krasheninnikov, J. Plasmas Phys. 77, 2011, 571-575.
[24] P. K. Shukla_ and B. EliassonarXiv:1009.5215v2, 2011.
[25] S. ChandrasekharAstrophys. J. 74, 1931,81.
[26] Iver H. Cairns and B. F. McMillan, Phys. Plasmas 12, 2005, 102110.
[27] S. D. Bale, F. S. Mozer, and T. Phan, Geophysical Research Letters 29, 2002, 2180.
[28] S. N. Walker, M. A. Balikhin, H. St. C. K. Alleyne, Y.Hobara, M. Andr´e, and M.W.Dunlop, Ann. Geophys. 26, 2008, 699–707.
[29] Xiaoyin Guan Hong Qin, Jian Liu and Nathaniel J. Fisch, Phys. Plasmas 20, 2013, 022502.
[30] MahmoudMoslehi-Fard, SamadSobhanianand LalehAtaeiSeresh, Publ. Astron. Obs. Belgrade 89, 2010, 351-354.
[31] C. Li, Z. Wu, H. Ren, W. Yang and P. K. Chu, Phys. Plasmas 19, 2012, 122114.
[32] W.Masood, B.Eliasson and P. K. Shukla, Physical Review E 81, 2010, 066401.

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