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Effect of quantum correction on thermal instability of self-gravitating two component plasma

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The effect of quantum correction on thermal instability of magnetized, viscous self-gravitating two component plasma has been studied by means of linear perturbation analysis. The dispersion relation for longitudinal and transverse mode of propagation has been described and discussed it for some limiting cases. The condition of instability as well as stability of the system has been discussed by applying Routh-Hurwitz criterion. It is found that due to the self-gravitation of the medium, the condition of thermal instability changes into the condition of radiative instability. Quantum parameter affects the condition of radiative instability in both longitudinal and transverse direction of propagation, while the magnetic field affects only in transverse direction. It is concluded that the effect of viscosity, temperature dependent heat-loss function; quantum parameter and magnetic field have a stabilizing influence, while the thermal conductivity and density dependent heat-loss function have destabilizing influence on the Jeans instability.

Keywords: ISM (Interstellar medium), Viscosity, Thermal conductivity, Radiative heat-loss functions, Quantum plasma, Collision frequency

1 Introduction

Thermal instability is one of the most important dynamical process in astrophysical plasmas. Thermal instability may be one of the primary cause for two phase medium with dense, cool clouds and hot, tenuous intercloud regions. The main motivation behind the studies of radiative condensation has been to explain the formation of dense and cool localized structures in astrophysical and laboratory plasmas, when their masses are less than those, required for gravitational contraction. A detailed analysis of thermal instability in the linear regime was given in a well-know paper by Field[1], and in large number of subsequent works (e.g., Heyvaerts[2], Balbus and Soker[3], Steele and Ib´ãnez[4], Burkert and Lin[5]). Recently, Stiele *et al*[6]. investigated the problem of clump formation due to thermal instabilities in a weakly ionized plasma with the help of a linear perturbation analysis.

The thermal and magneto-hydrodynamical instabilities play a crucial role in it, while gravity certainly is the dominant agent in star formation[7]. The combination of both thermal and gravitational linear stability is important, for example, for the structure formation in a protogalaxy[8], where condensation previously formed by thermal instability in a cooling medium become gravitationally unstable. In this direction, the problem of thermal instability in the fragmentation of a gravitational fluid discussed by Aggarwal and Talwar[9,10], Bora and Talwar[11] and Talwar and Bora[12] considering the effects of Hall current, electrical resistivity and finite electron inertia for an in-viscid medium. Recently, Gomez-Pelaez and Moreno-Insertis[13] have investigated the effect of self-gravity and thermal conduction on a cooling and expanding medium. They classified importance of various physical processes including self-gravity, background expansion, cooling, and thermal conduction according to their relative time-scales. Recently, Prajapati *et al*[14]. studied the self-gravitational instability of rotating viscous Hall plasma with arbitrary radiative heat-loss functions and electron inertia. The effect of radiative heat-loss functions and finite ion Larmor radius (FLR) corrections on the gravitational instability of infinite homogeneous viscous plasma have been investigated by Kaothekar and Chhajlani[15].

Frequently plasmas are not fully ionized but may be partially ionized so that the interaction between the neutral gas and the ionized fluid becomes important. In cosmic physics such situations occur in the solar photosphere, chromospheres and cool interstellar clouds. Thus, due to the importance of neutral ion collision many researchers investigated the problem of thermal and radiative instability in these regions. Fukue and Kamaya[16] revisited the effect of the ion-neutral friction of the two fluids on the growth of the thermal instability. The radiation condensation instability for both magnetized and unmagnetized partially ionized self-gravitating dusty astrophysical plasma has been investigated by Shukla and Sandberg[17]. Recently, Dangarh *et al*[18]. studied the effect of radiation and electron inertia on the Jeans instability of partially ionized plasma. Patidar *et al*[19]. in recent study, consider the problem of radiative instability of rotating two-component plasma under the effect of electron inertia but does not include the effect of Hall current and permeability.

Another important parameter in the study of thermal and gravitational instability problem is the quantum effect. In the interiors of compact astrophysical objects such as white dwarfs, neutron stars, magnetars, and supernovas, where the density can reach ten orders of magnitude that of ordinary solids, the study of quantum effects becomes important. Gardner[20] has given the quantum hydro-dynamic (QHD) model for semiconductor physics to describe the transport of charge, momentum and energy in plasmas. The quantum magneto-hydrodynamic (QMHD) model was obtained by Haas[21] with the help of QHD model with magnetic field based on the Wigner-Maxwell equations. This QMHD model is adopted by Ren *et al*[22]. in the study of Jeans instability in quantum magnetoplasma considering effect of electrical resistivity. Lundin *et al*[23]. also used the QMHD model to investigate the problem of Jeans instability of spin quantum plasma in the presence of a magnetic field. Shukla and Stenflo[24] investigated the Jeans instability of self-gravitating astrophysical quantum dusty plasma. The evaluation of dust acoustic waves in a self-gravitating dusty plasma with trapped electron and non-isothermal ions has been demonstrated by Misra and Roy Chowdhury[25]. Misra *et al*[26]. have investigated the electrostatic acoustic modes in a self-gravitating collisional dusty plasma in the presence of variable-charge impurities. The Jeans instability in a homogeneous cold dusty plasma in the presence of a magnetic field and quantum corrections was examined by Salimullah *et al*[27]. Furthermore, Misra and Roy Chowdhury[28] studied the amplitude modulations of the Dust Acoustic and Ion Acoustic waves. They demonstrated the existence of the modulational instability and envelope solitons in quantum plasmas. Thus, in the present analysis, the QMHD model on partially ionized self gravitating, and radiative plasma has been applied.

However, all these investigations assumed the medium to be a hydromagnetic fully ionized fluid. Some of them Fukue and Kamaya[16] have considered a partially ionized plasma system in the study of radiative instability. But none of the researcher has investigated the combined effect of other parameter with quantum effect. The present work is aimed to analyze the effects of neutral-ion collision and quantum correction on the thermal instability of self-gravitating plasma incorporating viscosity and magnetic field.

2 Linear Perturbation Analysis and Dispersion Relation

The motion of infinite extending homogeneous, self-gravitating two component quantum plasma subject to radiative heat-loss functions, thermal conduction and neutral-ion collision is considered. The system is embedded in a uniform magnetic field, $\vec{B}(0,\ 0,\ B)$, along z direction. The quantum magnetization of fluid due to electron spin is not considered in the present paper and taking the magnetic field classically. Following Haas[21], the governing quantum magneto-hydrodynamic equations are:

$$\rho\frac{du}{dt} = -\nabla p + \rho\nabla\Phi + \frac{\hbar^2\rho}{2m_e m_i}\nabla\left(\frac{\nabla^2\sqrt{\rho}}{\sqrt{\rho}}\right)$$

$$\frac{1}{4\pi}(\nabla\times B)\times B + \rho\nu\left(\nabla^2 u\right) + \rho_d\nu_c\left(u_n - u\right) \qquad \ldots(1)$$

$$\frac{du_n}{dt} + \nu_c\left(u_n - u\right) = 0. \qquad \ldots(2)$$

$$\frac{\partial\rho}{\partial t} + \rho\nabla.u = 0 \qquad \ldots(3)$$

$$\nabla^2\Phi + 4\pi G\rho = 0. \qquad \ldots(4)$$

$$\frac{\partial \mathrm{B}}{\partial t} = \nabla\times\left(u\times B\right) \qquad \ldots(5)$$

$$\frac{1}{(\gamma-1)}\frac{\partial p}{\partial t} - \frac{\gamma}{(\gamma-1)}\frac{p}{\rho}\frac{\partial\rho}{\partial t} + \rho\mathcal{L} + \nabla.F = 0 \qquad \ldots(6)$$

Supplemented by the condition that the magnetic field is solenoidal $(\nabla .B = 0)$. Here $d / dt \equiv \partial / \partial t + \nabla .u$ is the Lagrangian time derivative, ρ the mass density of fluid, ρ_d the density of neutral particles, u the velocity, G the gravitational constant, T the temperature, Φ the gravitational potential, p the pressure, $\gamma = 5/3$ is adiabatic index, v_c the collision frequency between two components of plasma, v the viscosity of the medium, $\hbar$ is the Planck constant divided by 2π. The quantum tunneling effects are inserted in Eq. (1) described by Bohm potential. Here in Eq. (6), $\mathcal{L}(T,\rho)$ is radiative heat loss rate per unit volume and the conductive heat flux F is given by:

$$F = -\lambda \nabla T . \quad \ldots(7)$$

where λ is the coefficient of thermal conductivity. In practices, linearizing the equations of the problem given in Eqs (1)-(6) with perturbations of the form:

$$f = f_0 + f e^{i(k_x x + k_z z + \omega t)}, \quad \ldots(8)$$

where f_0 is the unperturbed quantity, $f << f_0$, ω is the perturbation frequency and k_x and k_z are, respectively, X and Z components of the perturbation wave vector. Using Eq. (8) in Eqs (1) to (6) with Eq. (7), we obtain the four linear equations in terms of the amplitude components u_x, u_y, u_z, s as:

$$\left(\sigma\sigma' + v_k + \frac{k^2V^2}{\sigma}\right)u_x + \frac{ik_x}{k^2}\left(\Omega_R^2 + \frac{\hbar^2k^4}{4m_em_i}\right)s = 0 \quad \ldots(9)$$

$$\left(\sigma\sigma' + v_k + \frac{k_z^2V^2}{\sigma}\right)u_y = 0. \quad \ldots(10)$$

$$(\sigma\sigma' + v_k)u_z + \frac{ik_z}{k^2}\left(\Omega_R^2 + \frac{\hbar^2k^4}{4m_em_i}\right)s = 0. \quad \ldots(11)$$

$$\left(\frac{ik_xk^2V^2}{\sigma}\right)u_x - \left(\sigma^2\sigma' + \sigma v_k + \Omega_R^2 + \frac{\hbar^2k^4}{4m_em_i}\right)s = 0 \quad \ldots(12)$$

Here $\sigma = i\omega$, $\sigma' = \left(1 + \dfrac{bv_c}{\sigma + v_c}\right)$,

$b = \dfrac{\rho_d}{\rho_0}$, $v_k = vk^2$, $\Omega_R^2 = \dfrac{\sigma\,\Omega_j^2 + \Omega_I^2}{\sigma + \beta}$,

$\Omega_j^2 = k^2S_a^2 - 4\pi G\rho_0$,

$\Omega_I^2 = k^2\alpha - 4\pi G\rho_0\beta$,

$\alpha = (\gamma - 1)\left(\mathcal{L}_T T_0 - \mathcal{L}_\rho \rho_0 + \dfrac{\lambda k^2 T_0}{\rho_0}\right)$,

$\beta = (\gamma - 1)\left(\dfrac{\mathcal{L}_T T_0 \rho_0}{p_0} + \dfrac{\lambda k^2 T_0}{p_0}\right)$,

with $\mathcal{L}_\rho \equiv \partial\mathcal{L} / \partial\rho$ and $\mathcal{L}_T \equiv \partial\mathcal{L} / \partial T$; $V = B_0 / \sqrt{4\pi\rho_0}$, is Alfven velocity, $\rho / \rho_0 = s$, s denotes the condensation of the medium, $S_a = \sqrt{\gamma p_0 / \rho_0}$, is the adiabatic sound speed in the medium.

The non-trivial solution of the determinant of the matrix obtained from Eqs (9) to (12) with u_x, u_y, u_z, s having various coefficients that should vanish is to give the following dispersion relation:

$$\left(\sigma\sigma' + v_k + \frac{k_z^2V^2}{\sigma}\right)(\sigma\sigma' + v_k)\left[\left(\sigma\sigma' + v_k + \frac{k^2V^2}{\sigma}\right)\times\left(\sigma^2\sigma' + \sigma v_k + \Omega_R^2 + \frac{\hbar^2k^4}{4m_em_i}\right) - \frac{k_x^2V^2}{\sigma}\left(\Omega_R^2 + \frac{\hbar^2k^4}{4m_em_i}\right)\right] = 0 \quad \ldots(13)$$

This is the most general dispersion relation derived in this present work, describing the evaluations of perturbations in a self-gravitating, viscous two component quantum plasma subject to radiative heat-loss functions and thermal conduction in the presence of external magnetic field.

The dispersion relations obtained by Dangarh *et al*[18]. and Ren *et al*[22]. may be derived from Eq. (13) as its special cases. Thus Eq. (13) is modified form of the dispersion relations obtained by Dangarh *et al*[18]. and Ren *et al*[22]. due to the combined influence of viscosity, quantum effect, neutral-ion collision, thermal and radiative effect. The above dispersion relation given in Eq. (13) is very lengthy then, it is convenient to discuss this dispersion relation for longitudinal and transverse propagation separately.

We also discuss the stability of the system using Routh-Hurwitz criterion.

3 Analysis of the Dispersion Relation

3.1 Longitudinal mode of propagation ($k \| B$)

For this case, we assume all the perturbations longitudinal to the direction of the magnetic field i.e. ($k_z = k$, $k_x = 0$). Thus with this assumption, dispersion relation given in Eq. (13) splits in three modes of propagation, showing the effect of different parameters considered in the present problem, corresponding to the equations.

$$\left(\sigma\sigma' + v_k\right) = 0 \qquad \ldots(14)$$

$$\left(\sigma\sigma' + v_k + \frac{k^2V^2}{\sigma}\right) = 0 \qquad \ldots(15)$$

$$\left(\sigma^2\sigma' + \sigma\, v_k + \Omega_{\mathrm{R}}^2 + \frac{\hbar^2k^4}{4m_e m_i}\right) = 0 \qquad \ldots(16)$$

The first of these, Eq. (14) equating to zero, we get:

$$\sigma^2 + \sigma R_1 + v_k v_c = 0. \qquad \ldots(17)$$

where $R_1 = (1+b)v_c + v_k$. This dispersion relation represents the effect of viscosity and neutral-ion collision. If we ignore the viscosity then Eq. (17) is identical to Dangarh *et al*[18]. and also similar to Patidar *et al*[19]., when permeability of the porous medium is ignored. Here we can see that Eq. (17) cannot have a real positive root hence it satisfies the necessary and sufficient condition of stability. It means that viscosity of the medium stabilizes the system by damping the harmonics of perturbation and this damping effect is increased due to the presence of neutral particles. It is evident from Eq. (17) that this mode is unaffected by the presence of a magnetic field, thermal conductivity, self–gravitation, radiative and quantum effects.

The second factor, Eq. (15) equating to zero, gives the dispersion relation :

$$\sigma^3 + \sigma^2 R_1 + \sigma\left(k^2V^2 + v_k v_c\right) + v_c k^2 V^2 = 0 \qquad \ldots(18)$$

Dispersion relation given in Eq. (18) represents Alfven mode of propagation due to the effect of magnetic field, modified by the effects of collision frequency and viscosity of the medium. Eq. (18) is the same as obtained by Dangarh *et al*[18]. when the effect of viscosity is ignored. Since the coefficients of Eq. (18) are all positive including the constant term, therefore, this equation cannot have a positive roots which means that system represented by Eq. (18) is stable.

In the absence of neutral particles $\left[v_c = 0\right]$, the dispersion relation given in Eq. (18) reduces to:

$$\sigma^2 + \sigma v_k + k^2V^2 = 0 \qquad \ldots(19)$$

The necessary condition for stability of the system is that Eq. (19) should have all positive coefficients, which is satisfied. The sufficient condition is that the Routh-Hurwitz criterion must be satisfied, according to which all the principal diagonal minors of the Hurwitz matrix must be positive for a stable system. For the quadratic Eq. (19), the principal diagonal minors of Hurwitz matrix are obtained as:

$$\Delta_1 = v_k > 0$$
$$\Delta_2 = \left[v_k^2 + v_k k^2 V^2\right] > 0$$

We find that all **Δ**'s are positive, which shows that a magnetized viscous plasma is stable even in the absence of neutral particles. Thus, Eq. (19) represents a stable Alfven mode modified by the dissipative effect of viscosity.

The last factor in Eq. (16) represents a self-gravitating mode incorporated the effects of neutral particles, viscosity, thermal conductivity, radiative heat-loss functions and quantum correction, but this mode is independent of magnetic field. It means that magnetic field does not affect the condition of instability in the direction of propagation, longitudinal to the magnetic field.

Now, to study the effect of radiative heat-loss functions, thermal conductivity and quantum correction we restrict our discussion of the dispersion relation, corresponding to Eq. (16), for following special cases of astrophysical literature.

3.1.1 Thermally non-conducting, non-radiating plasma without quantum effect $\left[\mathcal{L}(T,\rho) = 0, \lambda = 0, Q = 0\right]$

For this case of thermally non-conducting, non-radiating plasma medium without quantum effect ($\alpha = \beta = Q = 0$), the dispersion relation given in Eq. (16) reduces to:

$$\sigma^3 + \sigma^2 R_1 + \sigma\left(v_k v_c + \Omega_j\right) + v_c \Omega_j = 0 \quad \ldots(20)$$

This dispersion relation for self-gravitating fluid shows the combined effect of neutral particles, and viscosity of the medium. Here we can recover the basic equation of gravitational instability obtained by Jeans on ignoring the effect of viscosity and neutral-ion collision from Eq. (20). It is clear from Eq. (20) that, when $\Omega_j^2 < 0$, the product of the roots and at least one root of σ is positive hence, the system is unstable. Thus for the cases of Eq. (21) the condition of instability is:

$$\Omega_j^2 = \left(S_a^2 k^2 - 4\pi G\rho_0\right) < 0$$

$$k < k_j = \left(\frac{4\pi G\rho_0}{S_a^2}\right)^{1/2} \quad \ldots(21)$$

Here k_j is the Jeans wave number. Eq. (21) is original Jeans expression for instability. The Jeans length is given as $\lambda_j = S_a\sqrt{\pi / G\rho_0}$.

The fluid is unstable for all Jeans length $\lambda > \lambda_j$, of Jeans wave number $k<k_j$. It is evident from Eq. (21) that Jeans criterion of instability remains unchanged in the presence of neutral particles and viscosity of the medium.

3.1.2 Non-radiating, thermally non-conducting quantum plasma *[α = β = 0, Q ≠ 0]*

For non-radiating and thermally non-conducting fluid having quantum effect, the dispersion relation given in Eq. (16) reduces to:

$$\sigma^3 + \sigma^2 R_1 + \sigma\left[v_c v_k + \Omega_j^2 + \frac{\hbar^2 k^4}{4m_e m_i}\right] + \left(\Omega_j^2 + \frac{\hbar^2 k^4}{4m_e m_i}\right)v_c = 0 \quad \ldots(22)$$

This dispersion relation given in Eq. (22) shows a gravitating mode influenced by the effect of collision frequency, viscosity of the medium and quantum correction. If we remove the effect of neutral-ion collision and viscosity of the medium then the dispersion relation given in Eq. (22) reduces to Ren *et al*[22]. for finitely conducting medium. Also dispersion relation given in Eq. (22), in the absence of neutral-ion collision, is similar to that of Prajapati and Chhajlani[29] excluding Hall current and resistivity in their case. The condition of Jeans instability can be obtained from the constant term of dispersion relationgiven in Eq. (22), which is given by:

$$\frac{4\pi G\rho_0}{k^2} > S_a^2 + \frac{\hbar^2 k^2}{4m_e m_i} \quad \ldots(23)$$

The system is represented by Eq. (23) will be unstable if it holds the above condition. The above condition of instability given in Eq. (23) is identical to Ren *et al*[22]. and Prajapati and Chhajlani[29]. Thus, we find that collision frequency and viscosity parameter do not affect the condition for Jeans instability of quantum plasma.

Now we examine the dynamical stability of the system by applying the Routh-Hurwitz criterion on the dispersion relation given in Eq. (22). If the last term of Eq. (22) is positive, i.e. $\left(\Omega_j^2 + \frac{\hbar^2 k^2}{4m_e m_i}\right) > 0$, then all the coefficient of Eq. (22) will be positive, which is a necessary condition for the stability of the system. To obtain the sufficient condition, the principal diagonal minors of the Hurwitz must be positive and obtain as :

$$\Delta_1 = R_1 > 0$$

$$\Delta_2 = R_1\left[v_c v_k + \Omega_j^2 + \frac{\hbar^2 k^2}{4m_e m_i}\right] > 0$$

$$\Delta_3 = R_1\left[\Omega_j^2 + \frac{\hbar^2 k^2}{4m_e m_i}\right] v_c\, \Delta_2 > 0$$

These all Δ's are positive, thereby, satisfying the Routh-Hurwitz criterion, according to which Eq. (22) will not include any positive real root of σ or a complex root whose real part is positive. Hence, the system expressed by Eq. (22) is stable.

3.1.3 Thermally conductive, radiative plasma without quantum effect *(α ≠ 0, β ≠ 0, Q = 0)*

For this case we take the limit that $\alpha \neq 0$, $\beta \neq 0$, $Q = 0$. In this limit, Eq. (16) is reduced to the form:

$$\sigma^4 + \sigma^3\left(R_1 + \beta\right) + \sigma^2\left(v_k v_c + R_1\beta + \Omega_j^2\right) + \sigma\left[v_c\left(\beta v_k + \Omega_j^2\right) + \Omega_I^2\right] + v_c\Omega_I^2 = 0 \quad \ldots(24)$$

Eq. (24) is identical to that of Patidar *et al*[19]. taking ($\varepsilon = 1$, $K_1 = \infty$) for non porous and non permeable medium in their case. The condition of instability of the system can be obtained from the constant term of Eq. (24) as :

$$\Omega_I^2 = \left[\begin{array}{l} k^2\left(T_0\mathcal{L}_T - \rho_0\mathcal{L}_\rho + \dfrac{\lambda k^2 T_0}{\rho_0}\right) \\ -4\pi G\rho_0\left(\dfrac{T_0\rho_0\mathcal{L}_T}{p_0} + \dfrac{\lambda k^2 T_0}{p_0}\right)\end{array}\right] < 0 \qquad \ldots(25)$$

It is evident from condition of instability given in Eq. (25) that the Jeans criterion of instability is modified due to inclusion of thermal conductivity and radiative heat-loss functions. The condition of instability given in Eq. (25) is identical to that of obtained by Dangarh *et al*[18]. and Patidar *et al*[19]. also for finitely conducting medium. From inequality given in Eq. (25) the range of critical wave number k_{j3} is given as:

$$k_{j3} = \frac{1}{2^{1/2}}\left[\begin{array}{l}\left\{\dfrac{4\pi G\rho_0}{S_i^2} + \dfrac{\rho_0^2\mathcal{L}_\rho}{\lambda T_0} - \dfrac{\rho_0\mathcal{L}_T}{\lambda}\right\} \\ \pm\left\{\begin{array}{l}\left(\dfrac{4\pi G\rho_0}{S_i^2} + \dfrac{\rho_0^2\mathcal{L}_\rho}{\lambda T_0} - \dfrac{\rho_0\mathcal{L}_T}{\lambda}\right)^2 \\ + \dfrac{16\pi G\rho_0^2\mathcal{L}_T}{\lambda S_i^2}\end{array}\right\}^{1/2}\end{array}\right]^{1/2} \qquad \ldots(26)$$

If inequalities given in Eq. (26) is applied for a purely temperature dependent radiative heat-loss function $(\mathcal{L}_\rho = 0)$, increases with temperature $(\mathcal{L}_T > 0)$, then the condition of monotonic instability is given as $k < k_{j1}$. However, if instead the radiative heat-loss function decreases with temperature $(\mathcal{L}_T < 0)$, the instability arises for k^2 lying between the values $\dfrac{|\mathcal{L}_T|}{\lambda}$ and $\dfrac{4\pi G\rho_0}{S_i^2}$ for parallel propagation.

Furthermore, if it is considered that the radiative heat-loss function is purely density dependent $(\mathcal{L}_T = 0)$ then the condition of instability is given as:

$$k < k_{j4} = \left(\frac{4\pi G\rho_0}{S_i^2} + \frac{\rho_0^2\mathcal{L}_\rho}{\lambda T_0}\right)^{1/2} \qquad \ldots(27)$$

It is evident from inequality given in Eq. (27) that the critical wave number is increased or decreased, depending on whether the radiative heat-loss function is an increasing or decreasing function of the density.

3.1.4 Radiative quantum plasma $\left[\mathcal{L}(T,\rho) \neq 0, \lambda \neq 0, Q \neq 0\right]$

For this case, the dispersion relation given in Eq. (16) remains unchanged and after expansion gives:

$$\begin{aligned}&\sigma^4 + \sigma^3(R_1 + \beta) + \sigma^2\left(v_k v_c + R_1\beta + \Omega_j^2 + \frac{\hbar^2 k^4}{4m_e m_i}\right) \\ &+\sigma\left[v_c\left(\beta v_k + \Omega_j^2\right) + \Omega_I^2 + \frac{\hbar^2 k^4}{4m_e m_i}(\beta + v_c)\right] \\ &+v_c\left(\Omega_I^2 + \frac{\hbar^2 k^4}{4m_e m_i}\beta\right) = 0 \qquad \ldots(28)\end{aligned}$$

This dispersion relation represents a self-gravitating mode modified due to the presence of thermal conductivity, radiative heat-loss functions and quantum correction. The influence of magnetic field does not appear in this mode, longitudinal to the direction of magnetic field, of propagation. The constant term of Eq. (28) has at least one positive root it means that at least one value of σ is positive and this gives instability. Thus, from Eq. (28), the condition of instability of the system is given as:

$$\begin{aligned}&k^2\left[T_0\mathcal{L}_T - \rho_0\mathcal{L}_\rho + \frac{\lambda k^2 T_0}{\rho_0}\right] + \left(\frac{\hbar^2 k^4}{4m_e m_i} - 4\pi G\rho_0\right) \\ &\times\left[\frac{T_0\rho_0\mathcal{L}_T}{p_0} + \frac{\lambda k^2 T_0}{p_0}\right] < 0 \qquad \ldots(29)\end{aligned}$$

Eq. (29) represents the modified condition of radiative instability due to quantum effect. In the absence of quantum effect the above condition of instability is identical to Bora and Talwar[11] and also to Dangarh *et al*[18]. in longitudinal mode of propagation. Thus, this is the new and modified condition of radiative instability found in the present work. If we compare Eq. (28) with Eqs (24) and (23), we find that condition of Jeans instability is modified due to simultaneous presence of radiative and quantum effects.

For non-gravitating medium without Quantum corrections ($G = 0$, $Q = 0$) Eq. (28) becomes:

$$\sigma^4+\sigma^3\left(R_1+\beta\right)+\sigma^2\left(v_k v_c+R_1\beta+k^2S_a^2+\frac{\hbar^2k^4}{4m_em_i}\right)$$
$$+\left[v_c\left(\beta v_k+k^2S_a^2\right)+k^2\alpha+\frac{\hbar^2k^4}{4m_em_i}\left(\beta+v_c\right)\right]$$
$$+v_c\left(k^2\alpha+\frac{\hbar^2k^4}{4m_em_i}\beta\right)=0 \qquad \ldots(30)$$

Evidently, if $\alpha<0$, thus for dispersion relation given in Eq. (29), at least one real positive root must exist and the considered medium goes unstable for the condition given as:

$$\left[T_0\mathcal{L}_T-\rho_0\mathcal{L}_\rho+\frac{\lambda k^2T_0}{\rho_0}\right]+\frac{\hbar^2k^2}{4m_em_i}\left[\frac{T_0\rho_0\mathcal{L}_T}{p_0}+\frac{\lambda k^2T_0}{p_0}\right]<0 \qquad \ldots(31)$$

From Eq. (31) we see that quantum correction try to stabilize the system. If we neglect the effect of quantum correction, viscosity and collision frequency then the above dispersion relation given in Eq. (31) is identical to Field[1]. In the present case we have considered the effects of quantum correction, viscosity and neutral-ion collision but Field[1] has not considered these effects. Thus, in the present analysis both the dispersion relation and the condition of thermal instability get modified due to the presence of quantum effect but the viscosity and the collision frequency only modify the dispersion relation and does not affect the condition of thermal instability. On comparing Eqs (44) and (48) we see that consideration of self-gravitation modifies the thermal instability criterion into radiative instability criterion. Also from Eq. (31) it is clear that the growth rate of the dispersion relation given by Field[1] is modified due to the presence of quantum correction, viscosity, collision frequency and self-gravitation in our present case. Hence these are the new results in our present problem than that of Field[1].

For our convenience to show a better insight, the graphical presentation of the exact growth rate of the system represented by Eq. (28) we introduce dimensionless quantities, assuming $\left(\rho>>\rho_d\right)$ so that $\left(b<<1\right)$ and dividing by Eq. (28) by $\sqrt{4\pi G\rho_0}$, as:

$$\sigma^*=\frac{\sigma}{\sqrt{4\pi G\rho_0}},\ v_c^*=\frac{v_c}{\sqrt{4\pi G\rho_0}},\ k^*=\frac{k\,S_a}{\sqrt{4\pi G\rho_0}},$$
$$v_k^*=k^{*2}v^*,\ v^*=\frac{v\sqrt{4\pi G\rho_0}}{S_a^2},\ \Omega_j^{*2}=\left(k^{*2}-1\right),$$
$$\Omega_I^{*2}=(k^{*2}\alpha^*-\beta^*)\ \ \alpha^*=\frac{1}{\gamma}\left(\mathcal{L}_T^*+\lambda^*k^{*2}\right)-\mathcal{L}_\rho^*,$$
$$\beta^*=\left(\mathcal{L}_T^*+\lambda^*k^{*2}\right),\ \lambda^*=\frac{(\gamma-1)T_0\lambda\sqrt{4\pi G\rho_0}}{pS_a^2},$$
$$\mathcal{L}_T^*=\frac{(\gamma-1)T_0\rho_0\mathcal{L}_T}{\rho_0\sqrt{4\pi G\rho_0}},\ \mathcal{L}_\rho^*=\frac{(\gamma-1)\rho_0\mathcal{L}_\rho}{S_a^2\sqrt{4\pi G\rho_0}},$$
$$Q^*=\frac{\hbar^2k_j^2}{4m_em_i}$$

Numerical calculations were performed to determine the roots of σ from dispersion relation given in Eq. (28), as a function of wave number k for arbitrary values of different parameters involved, taking $\gamma = 5/3$. The variations in the growth rate σ^*, with wave number k^* are shown in Figs 1-4.

Growth rate σ^* as a function of wave number k^* for arbitrary values of viscosity $v^* = 0.0, 0.5, 1.0, 1.5$ keeping the other parameters to be fixed. $\mathcal{L}_T^* = Q^* = \lambda^* = \mathcal{L}_\rho^* = 2.0$

Figure 1 shows the growth rate of an unstable mode (positive imaginary roots of σ^*) against the non-dimensional wavelength (k^*) with variation in the

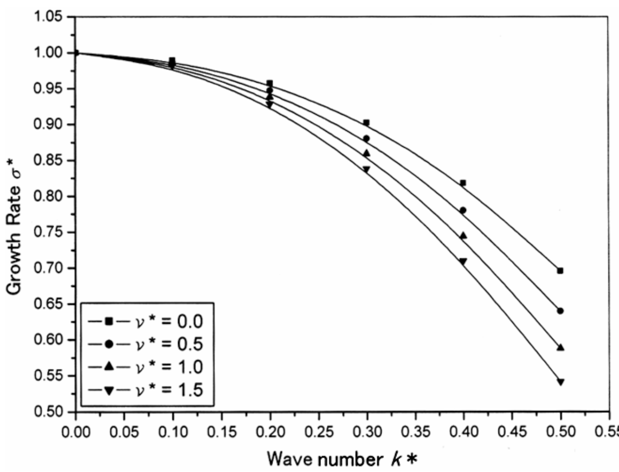

Fig. 1 — Growth rate σ^* as a function of wave number k^* for arbitrary values of viscosity ($v^* = 0.0, 0.5, 1.0, 1.5$) keeping the other parameters to be fixed. $\mathcal{L}_T^* = Q^* = \lambda^* = \mathcal{L}_\rho^* = 2.0$

viscosity parameter v^* (0.0, 0.5, 1.0, 1.5) keeping the values of other parameters to be fixed as $\mathcal{L}_T^* = Q^* = \lambda^* = \mathcal{L}_\rho^* = 2.0$.

The growth rate of unstable mode decreases with increasing value of viscosity of the medium (Fig. 1). Thus, we conclude that the viscous medium is more stable than the in-viscid medium that means the effect of viscosity is stabilizing.

Growth rate σ^* as a function of wave number k^* for arbitrary values of Quantum parameter Q^* = 0.0, 0.5, 1.0, 1.5 keeping the other parameters to be fixed. $\mathcal{L}_T^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.0$. Similarly, Fig.2 shows the growth rate of instability (positive imaginary root of σ^*) against the non-dimensional wave length (k^*) with variation in the quantum parameter Q^* (0.0, 0.5, 1.0, 1.5) keeping the values of other parameters to be fixed as $\mathcal{L}_T^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.0$.

From the preceding curve, it is found that the effect of the quantum parameter on the growth rate of unstable mode is stabilizing because increasing quantum parameter decreases the growth rate. Since the quantum parameter depends on plasma number density[30,31] (density of ionized particles), thus the increasing density (increasing ionization rate) tends the system towards stability.

Growth rate σ^* as a function of wave number k^* for arbitrary values of Temperature-dependent heat-loss function $\mathcal{L}_T^*$ = 0.0, 0.5, 1.0, 1.5 keeping the other parameters to be fixed. $Q^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.5$.

Figure 3 shows the growth rate of an unstable mode (positive imaginary roots of σ^*) against the non-dimensional wave length (k^*) with variation in the temperature-dependent heat-loss function $\mathcal{L}_T^*$ (0.0, 0.5, 1.0, 1.5) keeping the values of other parameters to be fixed as $Q^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.5$.

It is clear from Fig. 3 that the growth rate on the unstable mode decreases with increasing values of temperature dependent heat-loss function. The peak value of the growth rate is unaffected by the presence of the temperature-dependent heat-loss function and it is the same for all the values of $\mathcal{L}_T^*$ Thus, the effect of temperature dependent heat-loss function is to stabilize the system.

Growth rate σ^* as a function of wave number k^* for arbitrary values of thermal conductivity λ^* = 0.0, 2.0, 4.0, 6.0 keeping the other parameters to be fixed. $\mathcal{L}_T^* = Q^* = v^* = \mathcal{L}_\rho^* = 0.5$

Figure 4 shows the growth rate of an unstable mode (positive imaginary root of σ^*) against the non-dimensional wave length (k^*) with variation in the value of thermal conductivity λ^* (0.0, 2.0, 4.0, 6.0) keeping the values of other parameters to be fixed as $\mathcal{L}_T^* = Q^* = v^* = \mathcal{L}_\rho^* = 0.5$

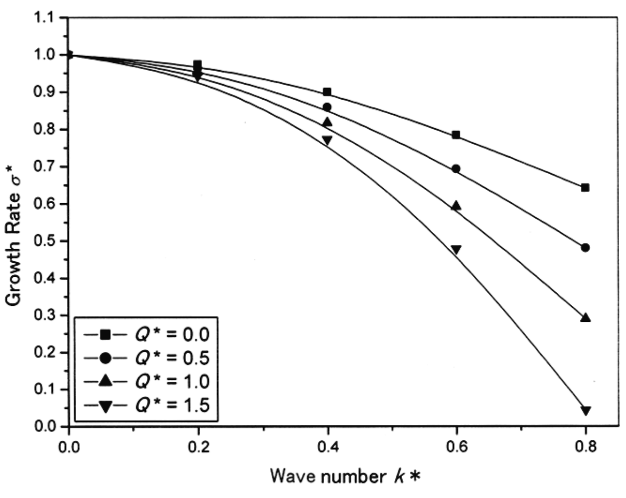

Fig. 2 — Growth rate σ^* as a function of wave number k^* for arbitrary values of Quantum parameter (Q^* = 0.0, 0.5, 1.0, 1.5) keeping the other parameters to be fixed. $\mathcal{L}_T^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.0$

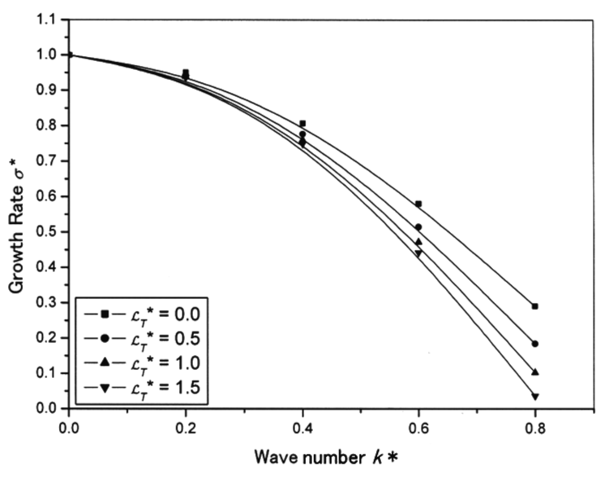

Fig. 3 — Growth rate σ^* as a function of wave number k^* for arbitrary values of Temperature-dependent heat-loss function ($\mathcal{L}_T^*$ = 0.0, 0.5, 1.0, 1.5) keeping the other parameters to be fixed. $Q^* = v^* = \lambda^* = \mathcal{L}_\rho^* = 1.5$

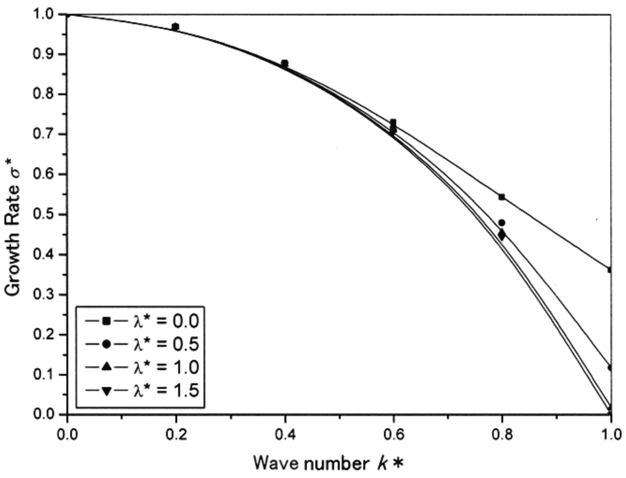

Fig. 4 — Growth rate σ^* as a function of wave number k^* for arbitrary values of thermal conductivity (λ^* = 0.0, 2.0, 4.0, 6.0) keeping the other parameters to be fixed. $\mathcal{L}_T^* = Q^* = v^* = \mathcal{L}_\rho^* = 0.5$

It is observed that the thermal conductivity has a reverse effect on the growth of unstable mode as compared to that of the viscosity, temperature dependent heat-loss function and quntum parameter (Fig. 4). In other words, due to increase in the value of thermal conductivity the growth rate of unstable mode increases. Hence, the thermal conductivity has a destabilizing influence on the growth rate of unstable mode.

3.2 Transverse propagation $(k \perp B)$

For this case, we assume all the perturbations are propagating perpendicular to the direction of the magnetic field, for, our convenience, we take $k_x = k$, and $k_z = 0$, the general dispersion relation reduces to:

$$(\sigma\sigma' + v_k)^3 \begin{bmatrix} \sigma(\sigma\sigma' + v_k) + k^2V^2 \\ +\left(\Omega_R^2 + \dfrac{\hbar^2 k^4}{4m_e m_i}\right) \end{bmatrix} = 0 \qquad \text{...(32)}$$

This is the general dispersion relation for transverse propagation which shows the simultaneous effect of magnetic field, quantum effect, viscosity, collision frequency, thermal conductivity and radiative heat-loss functions on the self-gravitational instability of the partially-ionized plasmas.

Dispersion relation given in Eq. (32) has two distinct factors, each represents different mode of propagation when equated to zero, separately. The first mode is the same as discussed in the dispersion relation given in Eq. (14) which represents the stable damped mode due to viscosity and collision frequency between two components of partially ionized plasma.

The second factor shows gravitating mode modified by the presence of magnetic field, thermal conductivity, radiative and quantum effects. Here the comparison of Eqs (32) and (16) reveals that in the transverse mode of propagation,the effect of magnetic field is coupled with gravitating conductive mode, it means that the condition of instability is affected by the Alfven velocity in this mode of propagation.

Now to investigate the separate and simultaneous effects of quantum correction, magnetic field, radiative heat-loss functions and thermal conductivity, we restrict our discussion to the second factor of dispersion relation given in Eq. (32), for following limiting cases of astrophysics.

3.2.1 Magnetized, radiative plasma without quantum effect

For this limiting case we have $\left[\mathcal{L}(T,\rho) \neq 0, V \neq 0, Q = 0\right]$. The second factor of Eq. (32), under this limitation, equating to zero and substituting the values of σ' and Ω_R^2 ,we get:

$$\sigma^4 + \sigma^3\alpha_1 + \sigma^2\alpha_2 + \sigma\alpha_3 + \alpha_4 = 0 \qquad \text{...(33)}$$

where $\alpha_1 = (R_1 + \beta)$

$$\alpha_2 = \left(v_k v_c + R_1\beta + \Omega_j^2 + k^2V^2\right)$$

$$\alpha_3 = \left[\beta v_k v_c + k^2V^2(\beta + v_c) + \Omega_j^2 v_c + \Omega_I^2\right]$$

$$\alpha_4 = \left[v_c\left(\Omega_I^2 + k^2V^2\beta\right)\right]$$

This dispersion relation for transverse propagation shows the combined influence of thermal conductivity, viscosity, neutral-ion collision, radiative heat-loss functions and quantum effect on the self-gravitation instability of partially-ionized plasmas in the presence of external magnetic field. The condition of instability is obtained from dispersion relation given in Eq. (33) as:

$$\left(k^2\alpha + k^2V^2\beta - 4\pi G\rho_0\beta\right) < 0 \qquad \text{...(34)}$$

This is the modified condition of radiative instability due to Alfven velocity (magnetic field). This condition of instability is the same as the condition of instability obtained by Dangarh *et al*[18].

and Patidar *et al*[19]. for transverse mode of propagation. Now, on comparing Eqs (34) and (25), we can conclude that the strength of magnetic field affects the condition of instability only in the direction of propagation transverse to the magnetic field. It is also concluded that the collision frequency and viscosity of the medium do not take part in condition of instability but their presence in the dispersion relation indicates that the growth rate of instability is modified due to these parameters.

If the fluid expressed by Eq. (33) does not contain radiative heat-loss functions then the critical wave number below which the system is unstable is obtained from the constant terms of Eq. (33) and is given by:

$$k_{j5}^2 = \frac{\gamma k_j^2}{\left(1+\frac{V^2}{S_i^2}\right)} \quad \text{...(35)}$$

If the radiative heat-loss functions are included in a thermally non-conducting configuration, the corresponding value of critical wave number is given by:

$$k_{j6}^2 = \gamma k_j^2 \left[\frac{T_0 \mathcal{L}_T}{T_0 \mathcal{L}_T \left(1+\frac{V^2}{S_i^2}\right) - \rho_0 \mathcal{L}_\rho}\right] \quad \text{...(36)}$$

The disturbance with a wave number $k < k_{j6}$ is unstable, where for $k < k_{j6}$, the disturbance is stable. Thus, it is clear that the configurations becomes unstable for all perturbation wave numbers if :

$$T_0 \mathcal{L}_T \left(1+\frac{V^2}{S_i^2}\right) > \rho_0 \mathcal{L}_\rho \quad \text{...(37)}$$

It is clear from Eq. (37) that the critical wave number vanishes if the radiative heat-loss functions are independent of temperature $\mathcal{L}_T = 0$ and if the radiative heat-loss functions are independent of density of the medium then the Jeans critical wave number is given by Eq. (21). In the general case when both the radiative heat-loss functions and thermally conductive effect are present simultaneously then it can be seen by a little simplification of Eq. (33) that the critical Jeans wave number is given by:

$$2\left(1+\frac{V^2}{S_i^2}\right)k_{j7}^2 = \left[\begin{array}{l}\left\{\frac{4\pi G\rho_0}{c^2}+\frac{\rho_0^2\mathcal{L}_\rho}{\lambda T_0}-\frac{\rho_0\mathcal{L}_T}{\lambda}\left(1+\frac{V^2}{S_i^2}\right)\right\} \\ \pm\left\{\begin{array}{l}\left(\frac{4\pi G\rho_0}{c^2}+\frac{\rho_0^2\mathcal{L}_\rho}{\lambda T_0}-\frac{\rho_0\mathcal{L}_T}{\lambda}\left(1+\frac{V^2}{S_i^2}\right)\right)^2 \\ +\frac{16\pi G\rho_0^2\mathcal{L}_T}{\lambda S_i^2}\left(1+\frac{V^2}{S_i^2}\right)\end{array}\right\}\end{array}\right]^{1/2} \quad \text{...(38)}$$

The medium is unstable for wave number $k < k_{j7}$. It may be noted here that the critical wave number involves, derivative of temperature-dependent and density-dependent radiative heat-loss function, thermal conductivity of the medium and the magnetic field.

3.2.2 Magnetized, non radiative quantum plasma

For this special case, we will apply the limitations, $\left[\mathcal{L}(T,\rho)=0, V\neq 0, Q\neq 0\right]$ to the second factor of Eq. (31), hence we get:

$$\sigma^2 + \sigma v_k + \left(k^2V^2 + \Omega_j^2 + \frac{\hbar^2 k^4}{4m_e m_i}\right) = 0 \quad \text{...(39)}$$

This is the dispersion relation for magnetized infinite homogeneous viscous self-gravitating partially-ionized plasma medium incorporating quantum effect. Eq. (39) is the modified form of the dispersion relation given in Eq. (17) obtained by Prajapati and Chhajlani[29] due to the effect of neutral ion collision. The constant term of Eq. (38) has at least one positive root. This means that at least one value of σ is positive and this gives instability. Thus, from Eq. (39) we note that the condition of instability of the system is:

$$S_a^2 + V^2 + \frac{\hbar^2 k^2}{4m_e m_i} < \frac{4\pi G\rho_0}{k^2} \quad \text{...(40)}$$

Thus, the magnetic field and quantum effect modify the Jeans' expression. The above condition of instability is the same as obtained by Prajapati and Chhajlani[29] and also by Lundin *et al*[23]. in the transverse direction of propagation. Also we can recover the condition of instability given by Chandrasekhar[32] if we neglect the quantum term in

Eq. (40). From the comparison of Eqs (22) and (39), we conclude that in the transverse mode of propagation we get Alfven waves due to mutual interaction of sonic and magnetic waves for which the condition of instability is given by Eq.(40) in which along with the sonic speed, Alfven velocity and quantum effect are also introduced.

3.2.3 Magnetized, radiating quantum plasma

In this case, we have $\left[\mathcal{L}(T,\rho)\neq 0, V\neq 0, Q\neq 0\right]$. On putting this condition in dispersion relation given in Eq. (31), the second factor of dispersion relation given in Eq. (31) gives:

$$\sigma^4+\sigma^3 A_3+\sigma^2 A_2+\sigma A_1+A_0=0 \quad \ldots(41)$$

where $A_3=\left[R_1+\beta\right]$

$$A_2=\left[\Omega_j^2+k^2V^2+v_k v_c+R_1\beta+\frac{\hbar^2k^4}{4m_em_i}\right]$$

$$A_1=\left[\begin{array}{c}\beta v_k v_c+k^2V^2\left(\beta+v_c\right)+\Omega_j^2 v_c+\Omega_I^2\\ +\dfrac{\hbar^2k^4}{4m_em_i}\left(\beta+v_c\right)\end{array}\right]$$

$$A_0=\left[v_c\left(\Omega_I^2+\frac{\hbar^2k^4}{4m_em_i}\beta+k^2V^2\beta\right)\right]$$

Eq. (41) shows the radiative mode modified by the inclusion of quantum effect, self-gravitation and magnetic field. If we ignore the effect of quantum correction and viscosity, Eq. (41) reduces to Dangarh *et al*[19]. by taking electron inertia as unity in their case. The condition of instability can be obtained from the constant term A_0 of dispersion relation given in Eq. (41) as:

$$\left(\Omega_I^2+k^2V^2\beta+\frac{\hbar^2k^4}{4m_em_i}\beta\right)>0 \quad \ldots(42)$$

The inequality given in Eq. (42) represents the modified condition of radiative instability due to magnetic field, and quantum correction in the direction of propagation transverse to the magnetic field. In the absence of quantum correction, this condition of instability is identical to Dangarh *et al*[19]. and also identical to Aggrawal and Talwar[10] for transverse mode propagation. It is obvious that as the strength of the magnetic field increases the corresponding critical wave number decreases hence magnetic field has stabilizing influence on the growth rate of instability.

Now to discuss the separate effect of magnetic and density dependent heat-loss function on the growth rate of unstable modes, we solve Eq. (41) numerically by using the relation given in Eq. (20) with following additional dimensionless quantities:

$$V^*=\left(\frac{V\sqrt{4\pi G\rho_0}}{S_a}\right)$$

Numerical calculations were performed to determine the roots of σ from dispersion relation given in Eq. (41), as a function of wave number k for arbitrary values of different parameters involved, taking γ = 5/3. The variations in the growth rate σ^*, with wave number k^* are shown in Figs 5 and 6.

Growth rate σ^* as a function of wave number k^* for arbitrary values of magnetic field V^* = 0.0, 0.5, 1.0, 1.5 keeping the other parameters to be fixed. $\mathcal{L}_\rho^*$ = Q^* = $\mathcal{L}_T^*$ = 0.5, λ^*= 1.

Figure 5 shows the non-dimensional growth (positive imagining value of σ^*) versus non-dimensional wave number (k^*) with variation in the magnetic field V^* = 0.0, 0.5, 1.0, 1.5 keeping the values of other parameters to be fixed. $\mathcal{L}_\rho^*$ = Q^* = $\mathcal{L}_T^*$ = 0.5, λ^*= 1.

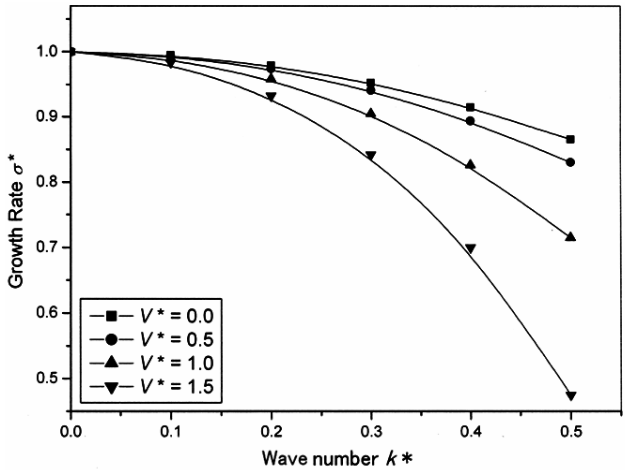

Fig. 5 — Growth rate σ^* as a function of wave number k^* for arbitrary values of magnetic field (V^* = 0.0, 0.5, 1.0, 1.5) keeping the other parameters to be fixed. $\mathcal{L}_\rho^*$ = Q^* = $\mathcal{L}_T^*$ = 0.5, λ^*= 1.

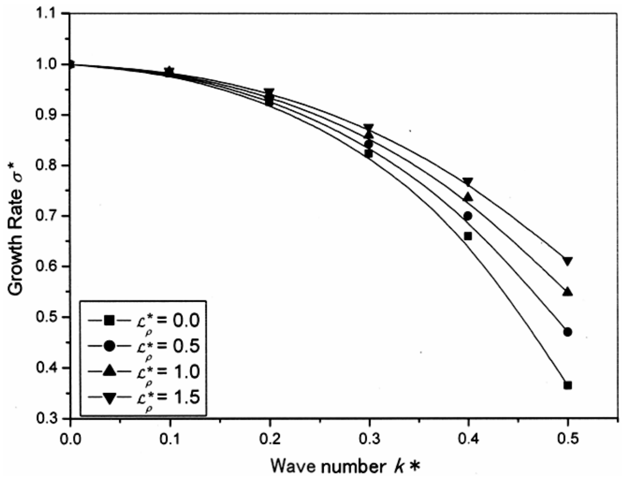

Fig. 6 — Growth rate σ^* as a function of wave number k^* for arbitrary values of density-dependent heat-loss function ($\mathcal{L}_\rho^*$ = 0.0, 0.5, 1.0, 1.5) keeping the other parameters to be fixed. $Q^* = \mathcal{L}_T^* = 0.5$, $V^* = \lambda^* = 1.5$

We find that the growth rate of unstable mode decreases with increasing strength of magnetic field. The peak value of the growth rate is unaffected by the presence of the magnetic field and it is the same for all the values of V^*. Hence, the effect of magnetic field is stabilizing.

Growth rate σ^* as a function of wave number k^* for arbitrary values of density-dependent heat-loss function $\mathcal{L}_\rho^*$ = 0.0, 0.5, 1.0, 1.5 keeping the other parameters to be fixed. $Q^* = \mathcal{L}_T^* = 0.5$, $V^* = \lambda^* = 1.5$

In Figure 6 shows the non-dimensional growth (positive imagining value of σ^*) versus non-dimensional wave length (k^*) with variation in the density dependent heat-loss function $\mathcal{L}_\rho^*$ (0.0, 0.5, 1.0, 1.5) keeping the values of other parameter to be fixed as $Q^* = \mathcal{L}_T^* = 0.5$, $V^* = \lambda^* = 1.5$.

Figure 6 shows the density dependent heat-loss function which has similar effect on the growth rate as compared to that of the thermal conductivity, in other words, due to increase in the density dependent heat-loss function, the growth rate of the instability increases. Hence, the density dependent heat-loss function has a destabilizing influence on the growth rate of the instability.

In the transverse propagation, we obtain two separate mode of propagation, one of them is damped stable mode which shows the damping effect of the viscosity, enhanced by the presence of neutral particles. The second mode is self-gravitating Alfven mode influenced by quantum correction, thermal conductivity and radiative heat-loss functions. It is found that the condition of radiative instability depends upon the quantum parameter and magnetic field. From the dispersion relation given in Eq. (41), we find that the coefficients of σ in dispersion relation contain the parameters such as viscosity, neutral-ion collision frequency, quantum correction, thermal conductivity, magnetic field and radiative heat-loss functions, thus the growth rate is affected by the presence of these parameters.

By comparing Eqs (42) and (29), we found that magnetic field, quantum correction, thermal conductivity and radiative heat-loss functions affect the Jeans criterion in perpendicular direction to the magnetic field but in parallel direction to the magnetic field, the medium behaves as if it is non-magnetized for instability considerations.

4 Conclusions

The wave propagation in an infinite homogeneous self-gravitating viscous and magnetized partially ionized fluid incorporating thermal conductivity radiative heat-loss functions and quantum effect, has been investigated. The general dispersion relation is obtained, which is modified due to the presence of these parameters. This dispersion relation is reduced for longitudinal and transverse modes of propagation and further discussed for some limiting cases of our interest. In general, we find that the Jeans condition remains valid but the expression of the critical Jeans wave number is modified due to quantum effect. The effect of the viscosity parameter and collision frequency is found to stabilize the system in both the longitudinal and transverse modes of propagation.

In the case of longitudinal propagation, we found that the Alfven mode is modified by the viscosity and collision frequency of neutrals with ionized gases. The effect of the collision with neutrals does not affect the condition of instability of the quantum plasma. It is observed that the condition of thermal instability is modified due to self-gravitation and also by quantum effect. The thermal conductivity has a destabilizing influence and the temperature-dependent heat-loss function, viscosity and quantum parameter have stabilizing influence on the system.

In the transverse mode of propagation, the condition of thermal instability and the expression of critical wave number both are modified due to the presence of magnetic field, self-gravitation and quantum effect. We find that the magnetic field and quantum parameter have a stabilizing influence on the radiative instability of partially ionized quantum plasma. It is obtained that the gravitating thermal mode is affected by thermal conductivity, radiative heat-loss functions and quantum parameter. It is found that radiative critical wave number is the same as original Alfven critical wave number when the radiative heat-loss functions are independent of density of the fluid. Thus, the classical Jeans results regarding the rise of initial break up have been considerably modified due to the radiative heat-loss functions. Figure 5 shows the stabilizing influence of magnetic field while Fig. 6 is showing a destabilizing effect of density dependent heat-loss function on the growth rate of instability.

The results of the present analysis may be useful to understand the problem of wave propagation and thermal instability in self-gravitating dense strongly correlated systems (astrophysical plasma, inertial confinement plasma, laser produced plasma, semiconductor plasma). The results of the present study are applicable to understand the formation of white dwarf star and neutron star.

Dust impurities exist in the quantum plasma, forming a quantum dusty plasma thus the present work can be further extended in dusty plasma environment, considering the other non-ideal effects viz. spin magnetization, Hall current, rotation, finite ion Larmor radius corrections which play significant role in the protoplanet formation.

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