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Star Formation via Thermal Instability of Radiative Thermally Conducting Viscous Plasma with FLR Corrections in ISM

Sachin Kaothekar [a, *]

[a] Department of Physics, Mahakal Institute of Technology, India

Abstract

The process of star formation is one of the most fascinating processes in the astronomy and astrophysics. The effect of radiative heat-loss function and finite ion Larmor radius (FLR) corrections on thermal instability of infinite homogeneous viscous plasma has been investigated incorporating the effects of thermal conductivity, finite electrical resistivity and permeability for star formation. A general dispersion relation is derived using the normal mode analysis method with the help of relevant linearized perturbation equations of the problem. The wave propagation along and perpendicular to the direction of magnetic field has been discussed. Stability of the medium is discussed by applying Routh Hurwitz's criterion. We find that the presence of FLR corrections, radiative heat-loss function and thermal conductivity modifies the fundamental criterion of thermal instability. Numerical calculations have been performed to show the effect of various parameters on the growth rate of the thermal instability. From the curves we find that heat-loss function and FLR corrections have stabilizing effect on the growth rate of thermal instability. Our results are applicable in understanding the star formation in interstellar medium.

Keywords: thermal instability, star formation, radiative heat-loss function, thermal conductivity, FLR corrections.

1. Introduction

Thermal instability is one of the most prominent aspects for star formation process in interstellar medium. As soon as an affirmative temperature perturbation is finished in a thermal unbalanced middling, the perturbation develops and the emanation pace dwindles. This progression is deliberation to be probable in a quantity of astrophysical circumstances such as the gas in the interstellar medium, bunches of the galaxies and in the solar corona. The not as much of understandable is the comparative consequence of this development in an assortment of conditions. Thermal instability has lots of claims in astrophysical circumstances (e.g. star configuration, stellar environment, a cluster of interstellar medium, globular clusters and galaxy configuration and many more situations Meerson, 1966). The instability may be motivated by radiative cooling of optically skinny gas arrangement or by exothermic nuclear reactions (Schwarzschild, Harm, 1965).

Linear firmness hypothesis for a dilute gas standard with volumetric foundations and descend of liveliness in thermal equilibrium was build upped by Field, 1965; he recognize three

* Corresponding author
E-mail addresses: sac_kaothekar@rediff.com, sackaothekar@gmail.com (Sachin Kaothekar)

unbalanced manners, the isobaric manner (the pressure motivated formation of condensations not engross gravitation) and the two isentropic manners (the over steadiness of acoustic wave broadcast in contradictory ways). Hunter, 1970, 1971 lengthened these consequences to arbitrary non-stationary environment streams, illustrating that chilling dictates media are potentially more unbalanced then that in balance, while heating supply stabilization. The majority widespread submissions of thermal instability to interstellar standard and star configuration agreement with the isobaric manner that was utilized to give details of the scrutinized multi phase construction of the interstellar medium (Field 1965, Pikel'ner 1968, Goldsmith, Habing, 1969, Wolfircetal, 1995). In this bearing Aggarwal, Talwar, 1969 have argued magneto-thermal instability in a rotating gravitating fluid. Sharm, Prakash, 1975 have explored radiative transport and collisional consequences on thermal convective instability of a composit intermediate. McCray, Stien, 1975 have conceded out the exploration of thermal instability in supernova shell. Nusel, 1986 has argued the thermal instability in chilling flows. Panavano, 1988 has studied self regulating star arrangement in isolated galaxies: thermal instability in the interstellar medium. Iabnez, Sancher, 1992 have revised the propagation of sound and thermal waves in plasma with solar abundance. Bora and Talwar, 1993 have examined the magneto-thermal instability with finite electrical resistivity and Hall current, both for self-gravitating and non-gravitation arrangements. Prajapati et al., 2010 have argued the consequence of radiative heat-loss function and thermal conductivity on gravitational instability of fully ionized plasma with electron inertia, Hall current, rotation and viscosity. Szunzkiewicz, Millar, 1997 have examined the thermal stability of transonic accretion discs. Najad-Asghar, Ghanbari, 2003 have accepted out linear thermal instability and arrangement of clumpy gas clouds including the ambipolar transmission. Vasiliev, 2012 has explored the thermal instability in a collisionaly chilled gas. Najad-Asghar, 2007 has examined the configuration of fluctuations in a molecular slab via isobaric thermal instability. Stiele et al., 2006 have accepted out the problem of thermal instability in weakly ionized plasma. Nipotic, 2010 has explored thermal instability in rotating galactic coronae. Hobbs et al., 2012 have argued thermal instability in breezing galactic fuelling star configuration in galactic discs. Nipoti, Posti, 2013 have explored thermal instability of faintly magnetized rotating plasma. Choudhary, Sharma, 2016 have argued cold gas in clusture core: global constancy analysis and non linear simulations of thermal instability.

Along with this in above argued predicaments the consequence of finite ion Larmor radius is not judged. In lots of astrophysical circumstances such as in interstellar and interplanetary plasmas the estimate of zero Larmor radiuses is not applicable. Quite a lot of authors Rosenbluth et al., 1962, Roberts and Taylor, 1962, Jeffery and Taniuti, 1966, Vandakurov, 1964 have positioned out the significance of finite ion Larmor radius (FLR) consequences in the form of magnetic viscosity, on the plasma instability. Recently Ferraro, 2007 has exposed the steady consequence of FLR on magneto-rotational instability. Marcu, Ballai, 2007 have revealed the even out consequence of FLR on thermosolutal stability of two-component rotating plasma. Sharma, 1974 has exposed the even out effect of FLR on gravitational instability of rotating plasma. Bhatia, Chhonkar, 1985 have examined the steady consequence of FLR on the instability of a rotating layer of self-gravitating plasma. Herrnegger, 1972 has studied the effects of collision and gyroviscosity on gravitational instability in a two-component plasma and concluded that the critical wave number becomes smaller with increasing gyroviscosity for finite Alfven numbers and showed that Jeans criterion is changed by FLR for wave propagating perpendicular to magnetic field. Vaghela, Chhajlani, 1989 have examined the steady consequence of FLR on magneto-thermal stability of resistive plasma through porous medium with thermal conduction. Thus FLR consequence is a significant feature in argument of self-thermal instability and supplementary hydrodynamic instability.

In the light of above work, we find that Bora, Talwar, 1993 have measured the consequence of finite electrical resistivity, electron inertia, Hall current, thermal conductivity and radiative heat-loss function, but they neglect the effect of FLR corrections, viscosity, and permeability on thermal instability. Vaghela, Chhajlani, 1989 have measured the effect of finite electrical resistivity, viscosity, permeability and thermal conductivity, but they ignore the consequence of radiative heat-loss function on thermal instability. Aggarwal, Talwar 1969 have measured the result of viscosity, rotation, finite electrical resistivity, thermal conductivity and radiative heat-loss function, but they neglect the effect of FLR corrections, and permeability on thermal instability. Thus we discover that in these learning, Aggarwal, Talwar, 1969 and Bora, Talwar, 1993, the cooperative sway of, permeability, FLR corrections, radiative heat-loss function, viscosity, electrical resistivity, thermal conductivity and magnetic field on the thermal instability is not explored. Consequently in the at hand employment the thermal instability of magnetized plasma with FLR corrections, permeability, radiative heat-loss function, viscosity, thermal conductivity and finite electrical resistivity for thermal configuration is studied. The stability of the system is discussed by applying Routh-Hurwitz criterion. The above work is applicable to dense molecular clouds and star formation in interstellar medium.

2. Basic set of equations of the difficulty

We take for granted an infinite homogeneous, magnetized, porous, thermally conducting, radiating, viscous plasma having (FLR) corrections in the presence of magnetic field $\mathbf{B}$ (0, 0, B). The MHD equations of the difficulty with these consequences are written as

$$\rho\frac{d\mathbf{v}}{dt} = -\nabla p - \nabla\cdot\mathbf{P} + \rho\upsilon\nabla^2\mathbf{v} - \rho\,\upsilon\frac{\mathbf{v}}{K_1} + \frac{1}{4\pi}(\nabla\times\mathbf{B})\times\mathbf{B}, \tag{1}$$

$$\frac{1}{\gamma-1}\frac{dp}{dt} - \frac{\gamma}{\gamma-1}\frac{p}{\rho}\frac{d\rho}{dt} + \rho L - \nabla.(\lambda\nabla T) = 0, \tag{2}$$

$$p = \rho RT, \tag{3}$$

$$\frac{d\rho}{dt} + \rho\,\nabla.\mathbf{v} = 0, \tag{4}$$

$$\frac{\partial\mathbf{B}}{\partial t} = \nabla\times(\mathbf{v}\times\mathbf{B}),, \tag{6}$$

$$\nabla.\mathbf{B} = 0, \tag{7}$$

where $\mathbf{P}$ is the pressure tensor situates for finite ion gyration radius as given by Robert and Taylor (1962) is

$$P = -\rho\upsilon\left(\frac{\partial v}{\partial x} + \frac{\partial v}{\partial y}\right), \qquad P = \rho\upsilon\left(\frac{\partial v}{\partial x} + \frac{\partial v}{\partial y}\right),$$

$$P = 0, \qquad P = P = \rho\upsilon\left(\frac{\partial v}{\partial x} - \frac{\partial v}{\partial y}\right), \tag{8}$$

$$P = P = -2\rho\upsilon\left(\frac{\partial v}{\partial z} + \frac{\partial v}{\partial y}\right), \qquad P = P = 2\rho\upsilon\left(\frac{\partial v}{\partial x} + \frac{\partial v}{\partial z}\right).$$

The parameter υ_0 has the dimensions of the kinematics viscosity and called as magnetic viscosity defined as $\upsilon_0 = \Omega_L\, R_L^2/4$, where R_L is the ion-Larmor radius and Ω_L is the ion gyration frequency. Also $p, \rho, \upsilon, T, K, \lambda, R,$ and γ indicate the fluid pressure, density, kinematic viscosity, temperature, permeability, thermal conductivity, gas constant and ratio of two specific heats respectively. $L(\rho, T)$ is the radiative heat-loss purpose and depends on local values of density and temperature of the fluid. The convective derivative operator is given as

$$\frac{d}{dt} = \left(\partial_t + \mathbf{v}.\nabla\right), \tag{9}$$

where ∂_t stands for $\partial / \partial t$.

3. Linearized perturbation equations

The perturbation in fluid velocity, magnetic field, density, pressure, temperature and heat-loss function is given as $\mathbf{u}(u_x, u_y, u_z)$, $\boldsymbol{\delta B}$ ($\boldsymbol{\delta B}_x$, $\boldsymbol{\delta B}_y$, $\boldsymbol{\delta B}_z$), $\delta\rho$, δp, δT and L respectively. The linearized perturbation equations for such standard are

$$\rho \partial_t \boldsymbol{v} = -\nabla \delta p - \nabla \cdot \mathbf{P} + \rho \upsilon \nabla^2 \boldsymbol{v} - \rho \upsilon \frac{\boldsymbol{v}}{K_1} + \frac{1}{4\pi}(\nabla \times \boldsymbol{\delta B}) \times \mathbf{B}, \tag{10}$$

$$\frac{1}{\gamma - 1}\partial_t \delta p - \frac{\gamma}{\gamma - 1}\frac{p}{\rho}\partial_t \delta\rho + \rho\left[L_\rho \delta\rho + L_T \delta T\right] - \lambda \nabla^2 \delta T = 0, \tag{11}$$

$$\frac{\delta p}{p} = \frac{\delta T}{T} + \frac{\delta \rho}{\rho}, \tag{12}$$

$$\partial_t \rho + \rho \nabla . \boldsymbol{v} = 0, \tag{13, 14}$$

$$\partial \boldsymbol{\delta B} = \nabla \times (\boldsymbol{v} \times \mathbf{B}), \tag{15}$$

$$\nabla . \boldsymbol{\delta B} = 0, \tag{16}$$

where L_T, L_ρ are the partial derivatives of temperature dependent heat-loss function $(\partial L / \partial T)_\rho$ and density dependent heat-loss function $(\partial L / \partial \rho)_T$ respectively.

We take for granted that all the perturbed measure vary as

$$\exp\, i(\sigma t + k_x x + k_z z), \tag{17}$$

where σ is the frequency of harmonic disturbance, k_x and k_z are the wave numbers of the perturbations along x and z axes.

The constituents of equation (15) may be given as

$$\delta B_x = \frac{iB}{\omega} k_z v_x, \quad \delta B_y = \frac{iB}{\omega} k_z v_y, \quad \delta B_z = -\frac{iB}{\omega} k_x v_x. \tag{18}$$

merged equations (11) and (12), we obtain

$$\delta p = \frac{(A + \omega c^2)}{(\zeta + \omega)} \delta\rho, \tag{19}$$

where $\omega = i\sigma$ and $c = (\gamma p / \rho)^{1/2}$ is the adiabatic velocity of sound in the intermediate. The stricture A and ζ are specified as

$$A = (\gamma - 1)\left(T L_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho} \right),$$

$$\zeta = (\gamma - 1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p} \right). \tag{20}$$

Using equations (13)-(19) in equation (10) with equation (8), we may inscribe the subsequent algebraic equations for the mechanism of equation (10)

$$\left[\omega + \upsilon\left(k^2 + \frac{1}{K_1} \right) + \frac{V^2 k^2}{\omega} \right] v_x + \left[\upsilon_0 \left(k_x^2 + 2k_z^2 \right) \right] v_y + \frac{ik_x}{k^2} \Omega_T^2 \, s = 0 \,, \tag{21}$$

$$-\left[\varepsilon (k_x^2 + 2k_z^2) \right] v_x + \left[\omega + \varepsilon\upsilon\left(k^2 + \frac{1}{K_1} \right) + \frac{V^2 k_z^2}{\omega} \right] v_y - 2\varepsilon\upsilon k_x k_z v_z = 0, \tag{22}$$

$$2\upsilon k_x k_z u_y + \left[\omega + \upsilon\left(k^2 + \frac{1}{K_1} \right) \right] u_z + \frac{ik_z}{k^2} \Omega_T^2 \, s = 0. \tag{23}$$

Captivating divergence of equation (10) and using equations (13) to (19), we attain as

$$ik_x \frac{V k^2}{\omega} v_x + i\upsilon k_x \left(k_x^2 + 4k_z^2 \right) v_y - \left[\omega + \omega\,\upsilon\left(k^2 + \frac{1}{K_1} \right) + \Omega_T^2 \right] s = 0 \,, \tag{24}$$

where $s = \delta\rho/\rho$ is the condensation of the medium.

To acquire the dispersion relative, we have made subsequent replacements in above equations

$$\Omega_T^2 = \frac{\omega\Omega_j^2 + \Omega_I^2}{\omega + B}, \qquad \Omega_j^2 = c^2 k^2, \qquad \Omega_I^2 = k^2(\gamma - 1)\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho} \right),$$

$$N = \omega + \upsilon\left(k^2 + \frac{1}{K_1} \right), \qquad Q = N + \frac{V^2 k^2}{\omega}, \qquad M = N + \frac{V^2 k_z^2}{\omega},$$

$$P_1 = \omega N + \Omega_T^2, \quad D = \upsilon_0 (k_x^2 + 2k_z^2), \quad E = 2\upsilon_0 k_x k_z, \quad E_1 = ik_x \frac{V^2 k^2}{(\omega)}, \tag{25}$$

$$N_1 = ik_x \upsilon_0 \left(k_x^2 + 4k_z^2 \right), \qquad F = \frac{ik_x}{k^2} \Omega_T^2, \qquad F_1 = \frac{ik_z}{k^2} \Omega_T^2, \qquad V^2 = B^2/4\pi\rho \,.$$

4. Dispersion relation

The nontrivial explanation of the determinant of the matrix get hold of from equations (21) - (24) with v_x, v_y, v_z, s having various coefficients should disappear to give the subsequent dispersion relative

$$PQNM + 4NM\,\upsilon_0^2 k_x^2 k_z^2 - \frac{2\,\upsilon_0^2 k_x^2 k_z^2}{k^2} \Omega_T^2 Q(k_x^2 + 4k_z^2) + NP\upsilon_0^2 \left(k_x^2 + 2k_z^2 \right) + 2\,\upsilon_0^2 k_x^2 k_z^2 (k_x^2 + 2k_z^2)$$

$$\times \frac{V^2}{\omega}\Omega_T^2 - \frac{\upsilon_0^2 k_x^2}{k^2}\Omega_T^2 (k_x^2 + 2k_z^2) N \left(k_x^2 + 4k_z^2\right) - \frac{V^2 k_x^2}{\omega}\Omega_T^2 N M - 4\upsilon_0^2 k_x^4 k_z^2 \frac{V^2}{\omega}\Omega_T^2 = 0. \tag{26}$$

The dispersion relation (26) symbolizes the concurrent addition of radiative heat-loss function, FLR corrections, thermal conductivity, finite electrical resistivity, viscosity, permeability and magnetic field on thermal instability of plasma. In nonexistence of radiative heat-loss function the general dispersion relation (26) is identical to that of Vaghela and Chhajlani (1989). On abandoning the consequence of thermal conductivity and radiative heat-loss function dispersion relation (26) is identical to Sanghvi and Chhajlani (1986). In lack of radiative heat-loss purpose, thermal conductivity, finite electrical resistivity and viscosity the general dispersion relation (26) is identical to Sharma (1974) for non-rotational case. In nonexistence of FLR corrections, viscosity and dispersion relation (26) is identical to Bora and Talwar (1993) neglecting Hall current and electron inertia in that case. Also in absence of FLR corrections, viscosity, finite conductivity and dispersion relation (26) reduces to that obtained by Field (1965) for non-gravitating medium. Now we argue the general dispersion relation (26) for longitudinal and transverse wave propagation.

5. Analysis of the dispersion relation

5.1. Longitudinal mode of propagation (k||B)

In this case the perturbations are taken corresponding to the course of the magnetic field ($i.e.$ $k_x = 0,\ k_z = k$). The dispersion relation (26) reduces to

$$\left[\omega + \upsilon\left(k^2 + \frac{1}{K_1}\right)\right]\left\{\left[\omega + \upsilon\left(k^2 + \frac{1}{K_1}\right) + \frac{V^2 k^2}{\omega}\right] + 4\upsilon_0^2 k^4\right\}$$

$$\times\left[\omega^2 + \omega\,\upsilon\left(k^2 + \frac{1}{K_1}\right) + \frac{\omega\Omega_j^2 + \Omega_I^2}{\omega + \zeta}\right] = 0. \tag{27}$$

This dispersion relation represents the collective effect of permeability, viscosity, magnetic field strength, thermal conductivity, radiative heat-loss function and FLR corrections on thermal instability of plasma. On evaluate this dispersion relation (27) with dispersion relation (20) of Vaghela and Chhajlani (1989) we find that two features are the identical but the third feature is unlike and acquires customized because of radiative heat-loss function. Also on multiplying all the constituents of equation (27) we get the dispersion relation, which is an equation of degree eight in ω and it is awkward to inscribe such a extensive equation. If we eliminate the consequence of FLR corrections, viscosity, and permeability in the above relation then we recover the relation given by Bora and Talwar (1993) not including Hall current and electron inertia in their case. Hence the above dispersion relation is the customized form of equation (21) of Bora and Talwar (1993) due to the enclosure of, permeability, FLR corrections and viscosity, in our case and by neglecting Hall current and electron inertia in their case for longitudinal propagation in dimensional form. In at hand case we have believed the effects of, permeability, FLR corrections and viscosity, but Bora and Talwar (1993) have not believed these consequences. Thus the dispersion relation in the in attendance psychotherapy is customized due to the presence of permeability, FLR corrections and viscosity, but circumstance of instability is unchanged by the presence of FLR corrections, viscosity, and permeability. Thus we terminate that the, permeability, FLR corrections and viscosity of the medium have no effect on the situation of instability. Also it is clear that the expansion pace of dispersion relation given by Bora and Talwar (1993) gets tailored due to the attendance of FLR corrections, viscosity and permeability in the present case. Thus we bring to a close that medium, permeability, FLR corrections and viscosity, modify the development pace of instability in the present case. Hence these are the new result in our case than that of Bora and Talwar (1993).

The dispersion relation (27) has three dissimilar constituents and we argue each constituent separately. The first constituent of the dispersion relation (27) gives

$$\omega + \upsilon\left(k^2 + \frac{1}{K_1}\right) = 0. \tag{28}$$

This symbolizes a constant clammy manner customized by the attendance of viscosity, and permeability of the intermediate. Thus viscous is competent to become constant the expansion pace of the considered organization. The above method is unmoved by the company of FLR corrections, magnetic field strength, thermal conductivity and radiative heat-loss function. This dispersion relation is the same as to Vaghela and Chhajlani (1989).

The second feature of equation (27) on sweeping statement gives

$$\omega^4 + 2\left\{\upsilon\left(k^2 + \frac{1}{K_1}\right)\right\}\omega^3 + \left\{\left[\upsilon\left(k^2 + \frac{1}{K_1}\right)\right] + 2\left(V^2k^2\right) + 4\,\upsilon_0^2k^4\right\}\omega^2 + \left\{2\left[\upsilon\left(k^2 + \frac{1}{K_1}\right)\right]\left(V^2k^2\right)\right.$$

$$\left. + 8\eta k^2\upsilon_0^2k^4\right\}\omega + V^2k^2 = 0. \tag{29}$$

The above dispersion relation demonstrates the viscous magnetized medium having finite electrical resistivity, permeability and FLR corrections. This dispersion relation is identical to Vaghela and Chhajlani (1989). The above relation is sovereign of thermal conductivity and radiative heat-loss functions. Equation (29) is a four degree equation in power of ω having its all coefficients positive which is a required situation for the constancy of the arrangement. To accomplish the adequate circumstance the major diagonal minors of Hurwitz matrix must be constructive. On scheming we get all the principal diagonal minors encouraging. Hence equation (29) always symbolized stability.

For inviscid, infinitely conducting intermediate in nonattendance of FLR corrections $(\upsilon = \upsilon_0 = 0)$ equation (29) becomes

$$\omega^2 + V^2k^2 = 0. \tag{30}$$

This represents the pure Alfven mode.

For inviscid medium $(\upsilon = 0)$ equation (29) becomes

$$\omega^4 + 2(V^2k^2 + 2\,\upsilon_0^2k^4)\omega^2 + V^4k^4 = 0. \tag{31}$$

The roots of equation (31) are

$$\omega = \left[-\left(V^2k^2 + 2\,\upsilon_0^2k^4\right) \pm 2\upsilon_0 k^2\left(V^2k^2 + \upsilon_0^2k^4\right)\right]. \tag{32}$$

Hence FLR corrections modify the Alfven mode by changing the growth rate of the system. Equations (31) and (32) are the customized form of Vaghela and Chhajlani (1989) by intermediate.

The third component of the dispersion relation (27) on simplifying gives

$$\omega^3+\left[\upsilon\left(k^2+\frac{1}{K_1}\right)+(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2 T}{p}\right)\right]\omega^2+\left[(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2 T}{p}\right)\upsilon\left(k^2+\frac{1}{K_1}\right)\right.$$

$$\left.+(c^2k^2)\right]\omega+\left\{k^2(\gamma-1)\left(TL_T-\rho L_\rho+\frac{\lambda k^2 T}{\rho}\right)\right\}=0. \qquad (33)$$

This dispersion relation (33) corresponds to the joint influence of permeability, radiative heat-loss function, thermal conductivity and viscosity on the thermal instability of plasma. But there is no consequence of FLR corrections, finite electrical resistivity and magnetic field on the thermal instability of the considered system. In nonattendance of radiative heat-loss function the above relation (33) is identical to Vaghela and Chhajlani (1989). If the steady term of cubic equation (33) is a smaller amount than zero this agree to at least one positive real root which communicates to the instability of the organization. The circumstance of instability gained from unvarying term of equation (33) is given as

$$\left\{k^2(\gamma-1)\left(TL_T-\rho L_\rho+\frac{\lambda k^2 T}{\rho}\right)\right\}<0. \qquad (34)$$

The medium is unbalanced for wave number $k<k_{J1}$. Here it may be memorandum that the tailored critical wave number engrosses the derivatives of temperature dependent, density dependent heat-loss function and thermal conductivity of the medium. $c'=(p/\rho)^{1/2}$ is the isothermal velocity of sound in the intermediate. In nonattendance of permeability and viscosity, equation (33) is indistinguishable to Field (1965), as the viscosity and permeability of the medium have no consequence on the condition of instability. It is clear that the growth pace of the dispersion relation given by Field (1965) is getting customized due to the occurrence of viscosity and permeability in our present case. Hence these are the innovative verdicts in our case than that of Field (1965).

Fig. 1 demonstrates the outcome of k_λ^* on the enlargement pace of thermal instability for permanent values of other parameters. From curves it is clear that as the value of k_λ^* increases both the peak charge and the growth rate of thermal instability decreases. Thus the parameter k_λ^* moves the present system towards the stabilization. In Fig. 2 we have designed the enlargement pace of thermal instability against wave number for different values of the parameter k_T^*. From figure we terminate that as the value of k_T^* increase, the peak value of curves diminishes and the area of development pace also reduces. Hence, the presence of k_T^* also become constant the organization. In Fig. 3 we have exposed the consequence of viscosity on the expansion pace of thermal instability. Figure exhibits that on growing the worth of viscosity the enlargement rate of thermal instability reduces. Therefore, the parameters k_λ^*, k_T^* and ν^* viscosity stabilize the system.

To discuss the consequence of all stricture on the enlargement tempo of thermal instability we resolve equation (33) numerically by pioneer the following dimensionless quantities

To study the belongings of viscosity, and radiative heat-loss functions on the growth rate of thermal instability, we solve Eq. (33) numerically. Therefore Eq. (33) can be written in non-dimensional form with the help of following dimensionless quantities

$$\omega^*=\frac{\omega}{k_\rho c_s},\quad \upsilon^*=\frac{\upsilon k_\rho}{c_s},\quad k^*=\frac{k}{k_\rho},\quad k_\lambda^*=\frac{k_\rho}{k_\lambda},\quad k_T^*=\frac{k_T}{k_\rho}. \qquad (35)$$

Using Eq. (35), we write Eq. (33) in non-dimensional form as

$$\omega^{*3}+\left[\upsilon^{*}k^{*2}+k_{T}^{*}+k_{\lambda}^{*}k^{*2}\right]\omega^{*2}+c_{s}^{2}\left[\upsilon^{*}k^{*2}\left(k_{T}^{*}+k_{\lambda}^{*}k^{*2}\right)+k^{*2}\right]\omega^{*}+\frac{k^{*2}}{\gamma}\left(k_{T}^{*}-1+k_{\lambda}^{*}k^{*2}\right)=0. \qquad (36)$$

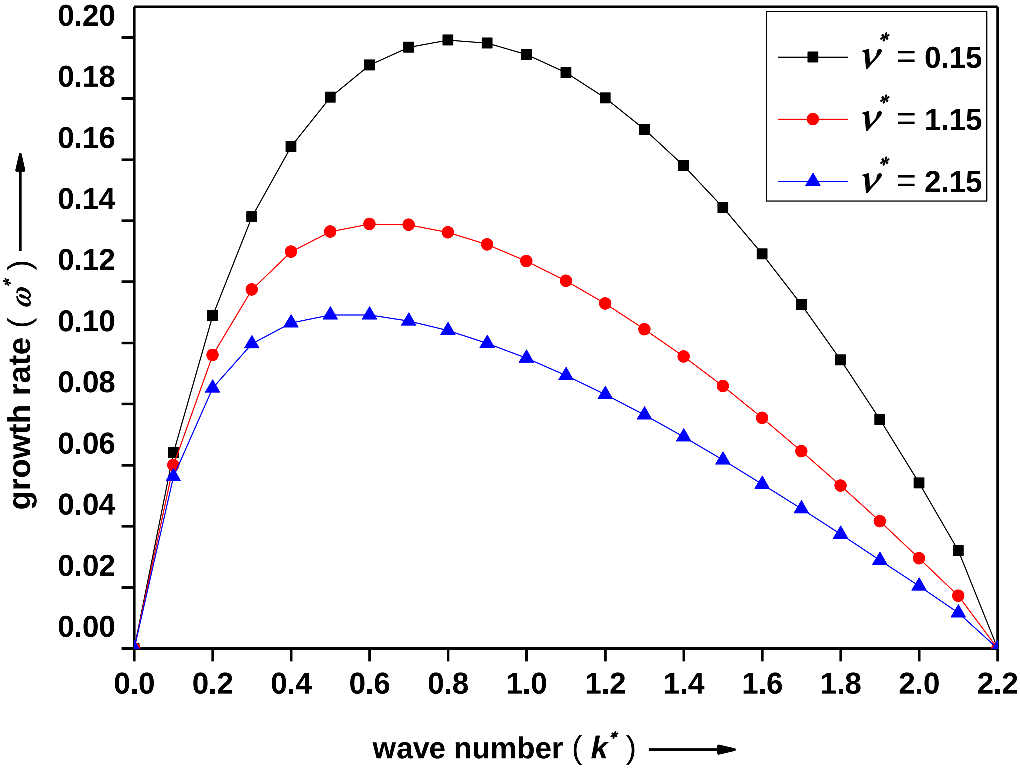

Fig. 1. The normalized growth rate (ω^{*}) as a function of normalized wave number (k^{*}) for different values of ν^{*} with k_{T}^{*} = 0.5 and $K_{1}^{*}=1$, $k_{\lambda}{}^{*}$ = 0.1.

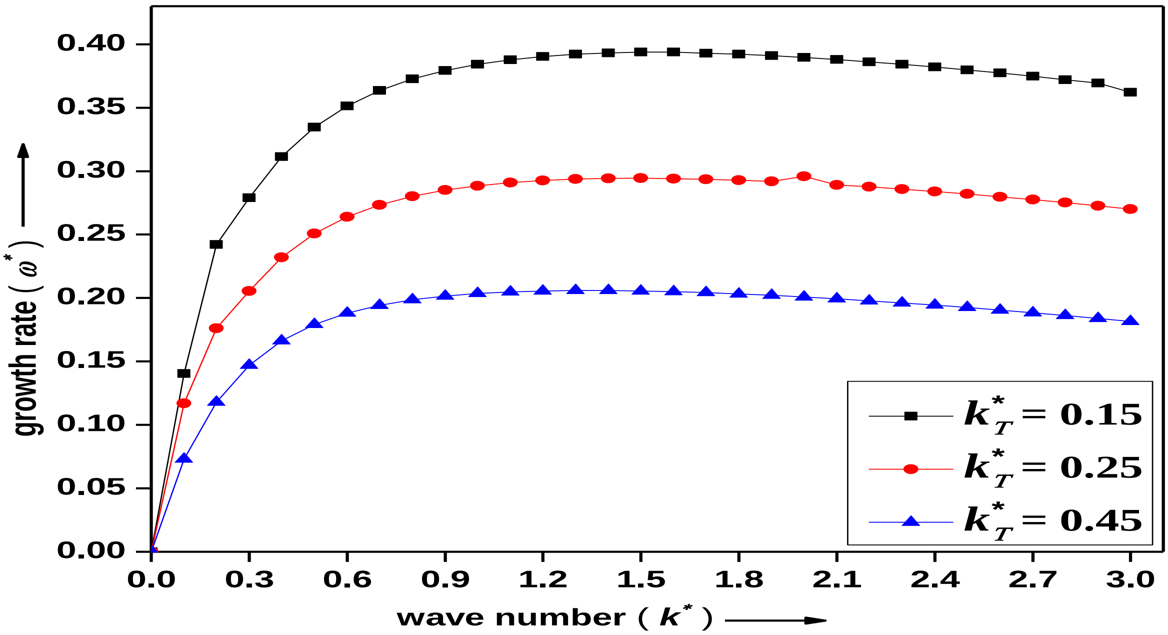

Fig. 2. The normalized growth rate (ω^*) as a function of normalized wave number (k^*) for different values of k_T^* with $k_\lambda^* = 0.01$ and $K_1^* = \upsilon^* = 1.0$

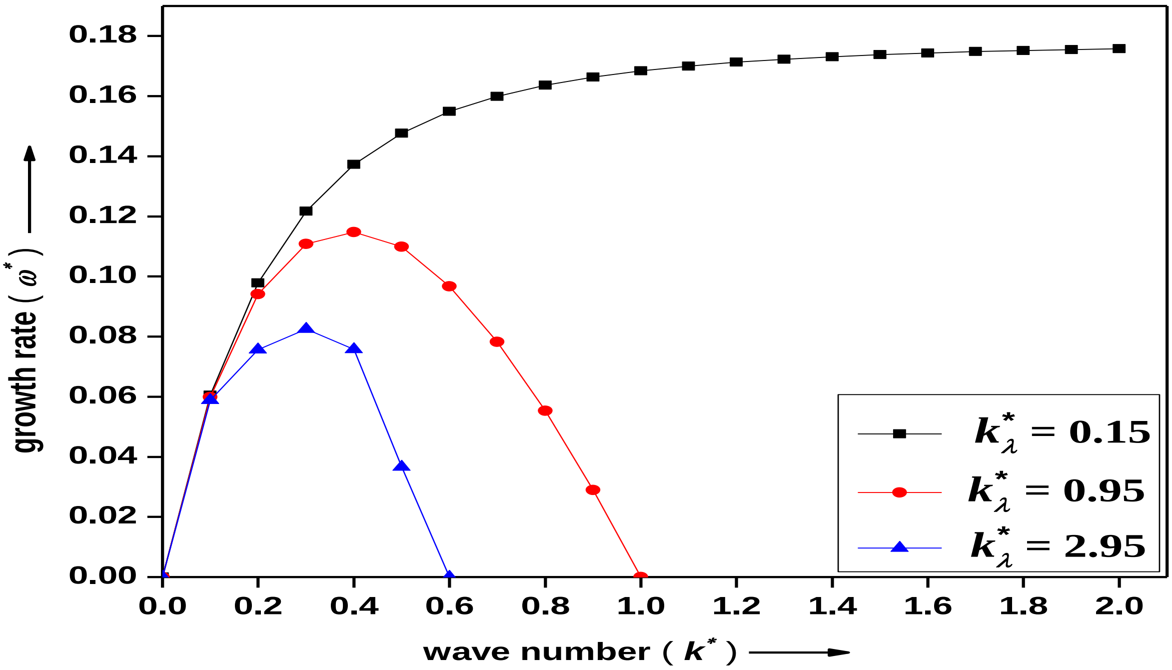

Fig. 3. The normalized growth rate (ω^*) as a function of normalized wave number (k^*) for different values of k_λ^* with $k_T^* = 0.5$ and $K_1^* = \upsilon^* = 1.0$.

To argue the constancy of the arrangement given by equation (33), if constant term of cubic equation (33) is superior to zero, then all the coefficients of the equation (33) must be positive. Equation (33) is a third degree equation in the power of ω having its coefficients positive, which is a compulsory circumstance for the stability of the organization. To achieve the adequate circumstance the principal diagonal minors of Hurwitz matrix must be positive. The principal diagonal minors are

$$\Delta_1 = \left\{ \upsilon\left(k^2 + \frac{1}{K_1}\right) + (\gamma - 1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right) \right\} > 0,$$

$$\Delta_2 = \upsilon\left(k^2 + \frac{1}{K_1}\right)\left[\Delta_1(\gamma - 1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right) + c^2k^2\right] + (\gamma - 1)k^2\rho L_\rho > 0, \quad (37)$$

$$\Delta_3 = \Delta_2\left\{k^2(\gamma - 1)\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho}\right)\right\} > 0.$$

If $\Omega_j^2 > 0, \Omega_I^2 > 0$ and $\gamma > 1$, then it is clear that all the Δs are positive hence organization symbolized by equation (33) is stable system.

For viscous, radiating, thermally non-conducting and self-gravitating porous medium $(\upsilon = L_{T,\rho} \neq 0, \lambda = 0)$ equation (33) becomes

$$\omega^3 + \left\{ \upsilon\left(k^2 + \frac{1}{K_1}\right) + \frac{\gamma L_T}{c_p} \right\}\omega^2 + \left\{ \upsilon\left(k^2 + \frac{1}{K_1}\right)\frac{\gamma L_T}{c_p} + c^2k^2 \right\}\omega$$

$$+ \frac{\gamma L_T}{c_p}\left\{k^2\left(c'^2 - \frac{pL_\rho}{TL_T}\right)\right\} = 0. \quad (38)$$

The condition of instability from constant term of equation (38) is

$$\left\{k^2\left(c'^2 - \frac{pL_\rho}{TL_T}\right)\right\} < 0, \quad (39)$$

Thus we terminate that for longitudinal wave propagation as given by equation (27) the system is unbalanced only for Jeans condition, else it is stable. Also for longitudinal wave propagation the Jeans criterion remains unchanged by FLR corrections, viscosity, magnetic field, finite electrical resistivity and permeability, but thermal conductivity and radiative heat-loss function modify the expression and the original instability criterion becomes radiative instability criterion.

5.2 Transverse mode of propagation ($\mathbf{k} \perp \mathbf{B}$)

In this case the perturbations are taken perpendicular to the way of the magnetic field $(i.e.\ k_x = k,\ k_z = 0)$. The dispersion relation (26) decreases to

$$\left\{\omega + \upsilon\left(k^2 + \frac{1}{K_1}\right)\right\}\left[\left\{\omega + \upsilon\left(k^2 + \frac{1}{K_1}\right)\right\}\left\{\omega^2 + \omega\,\upsilon\left(k^2 + \frac{1}{K_1}\right) + \frac{\omega V^2 k^2}{\omega}\right.\right.$$

$$+\frac{\omega\Omega_j^2+\Omega_I^2}{\omega+\zeta}\Bigg\}+\omega^2\upsilon_0^2k^4\Bigg]=0. \tag{40}$$

This dispersion relation (40) is customized due to the attendance of permeability, radiative heat-loss function, FLR corrections, thermal conductivity, viscosity, finite electrical resistivity and magnetic field. The dispersion relation (40) has two different mechanisms. The first constituent of the dispersion relation (40) symbolizes a steady viscous mode modified by the presence of permeability of the medium as argues in equation (28).

The second constituent of the dispersion relation (40) on make things easier gives

$$\omega^4+\left\{2\upsilon\left(k^2+\frac{1}{K_1}\right)+(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)\right\}\omega^3+\left\{2\upsilon\left(k^2+\frac{1}{K_1}\right)\left[(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)\right]\right.$$

$$+\upsilon^2\left(k^2+\frac{1}{K_1}\right)^2+V^2k^2+\upsilon_0^2k^4+c^2k^2\Big\}\omega^2+\left\{\left[(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)\right]\left[\upsilon\left(k+\frac{1}{K_1}\right)+\upsilon_0^2k^4\right]\right.$$

$$+V^2k^2\left[\upsilon\left(k^2+\frac{1}{K_1}\right)+(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)\right]+c^2k^2\left[\upsilon\left(k^2+\frac{1}{K_1}\right)\right]+\left[k^2(\gamma-1)\left(TL_T-\rho L_\rho+\frac{\lambda k^2T}{\rho}\right)\right]\Bigg\}\omega$$

$$+\left\{V^2k^2(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)+k^2(\gamma-1)\left(TL_T-\rho L_\rho+\frac{\lambda k^2T}{\rho}\right)\right\}=0. \tag{41}$$

The above dispersion relation symbolize the joint influence of thermal conductivity, radiative heat-loss function, FLR corrections, finite electrical conductivity, viscosity, permeability and magnetic field on thermal instability of plasma through porous medium. In nonappearance of radiative heat-loss function equation (41) is indistinguishable to Vaghela, Chhajlani, 1989. When unvarying term of equation (41) is a smaller amount than zero this allows at least one positive real root which communicates to the instability of the arrangement. The situation of instability obtained from unvarying term of equation (41) is given as

$$\left\{V^2k^2(\gamma-1)\left(\frac{T\rho L_T}{p}+\frac{\lambda k^2T}{p}\right)+k^2(\gamma-1)\left(TL_T-\rho L_\rho+\frac{\lambda k^2T}{\rho}\right)\right\}<0. \tag{42}$$

Thus to converse the consequence of each restriction (viz. heat-loss function, viscosity, permeability and FLR corrections) on the growth rate of unstable modes, we solve equation (41) numerically by introducing the following dimensionless measures

$$\omega^*=\frac{\omega}{k_\rho c_s},\quad \upsilon^*=\frac{\upsilon k_\rho}{c_s},\quad k^*=\frac{k}{k_\rho},\quad k_\lambda^*=\frac{k_\rho}{k_\lambda},\quad k_T^*=\frac{k_T}{k_\rho},\quad \upsilon_0{}^*=\frac{\upsilon_0k_\rho}{c_s}. \tag{43}$$

Using Eq. (43), we put pen to paper Eq. (41) in non-dimensional form as

$$
\begin{aligned}
&\omega^{*4} + \left\{ 2\upsilon^{*}\left(k^{*2} + \frac{1}{K_1^{*}}\right) + k_T^{*} + k_\lambda^{*} k^{*2} \right\}\omega^{*3} + \left\{ 2\upsilon^{*}\left(k^{*2} + \frac{1}{K_1^{*}}\right)\left[k_T^{*} + k_\lambda^{*} k^{*2}\right] + \upsilon^{*2}\left(k^{*2} + \frac{1}{K_1^{*}}\right)^2 \right. \\
&\left. + V^{*2}k^{*2} + \upsilon_0^{*2}k^{*4} + c^{*2}k^{*2} \right\}\omega^{*2} + \left\{ \left[k_T^{*} + k_\lambda^{*} k^{*2}\right]\left[\upsilon^{*}\left(k^{*2} + \frac{1}{K_1^{*}}\right) + \upsilon_0^{*2}k^{*4}\right] + V^{*2}k^{*2} \right. \\
&\times \upsilon^{*}\left(k^{*2} + \frac{1}{K_1^{*}}\right) + k_T^{*} + k_\lambda^{*} k^{*2} \Big] + c^{*2}k^{*2}\left[\upsilon^{*}\left(k^{*2} + \frac{1}{K_1^{*}}\right)\right] + \left. \frac{k^{*2}}{\gamma}\left[k_T^{*} + k_\lambda^{*} k^{*2} - 1\right] \right\}\omega^{*} \\
&+ \left\{ V^{*2}k^{*2}\left[k_T^{*} + k_\lambda^{*} k^{*2}\right] + \frac{k^{*2}}{\gamma}\left[k_T^{*} + k_\lambda^{*} k^{*2} - 1\right] \right\} = 0. \qquad (41)
\end{aligned}
$$

In Figures 4-8 the dimensionless expansion pace (ω^{*}) has been plotted touching the dimensionless wave number (k^{*}) to see the consequence of a variety of physical stricture such as viscosity, radiative heat-loss function and FLR corrections. It is clear from Fig. 4 that augmentation pace diminishing with increasing the value of viscosity. Thus the effect of viscosity is stabilizing. From Fig. 5 we see that as the value of k_λ^{*} augment the growth rate diminishes. Thus the consequence of limitation k_λ^{*} is also become constant.

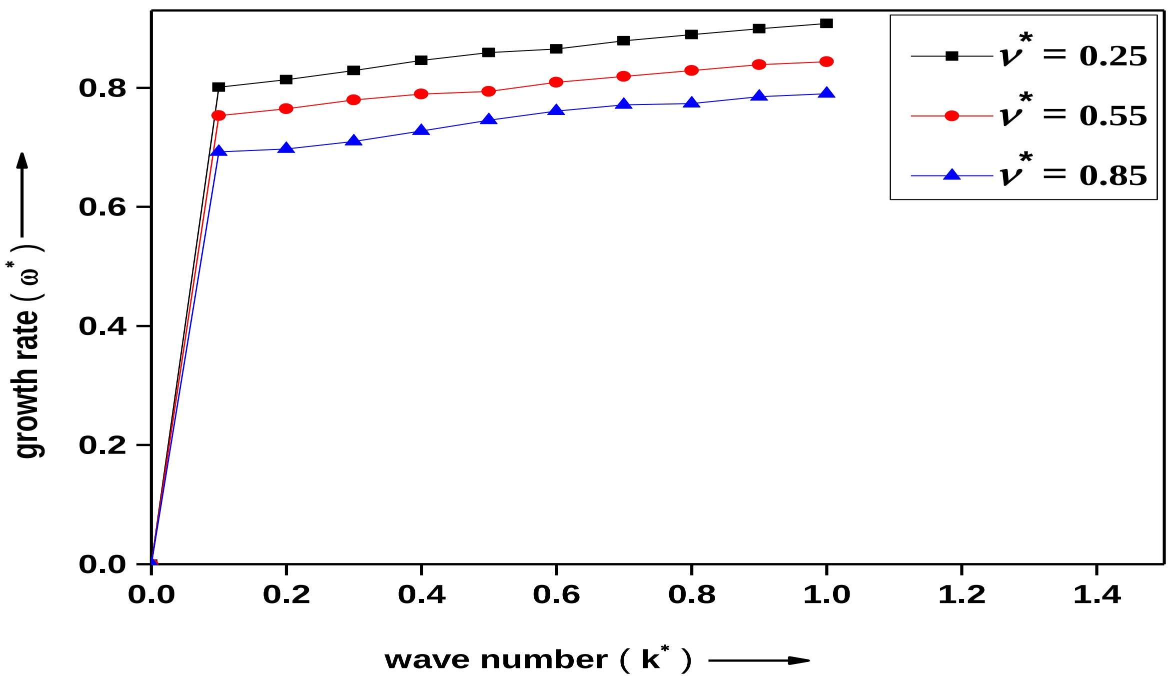

Fig. 4. The normalized growth rate (ω^{*}) as a function of normalized wave number (k^{*}) for different values of ν^{*} with k_T^{*} = 0.3 and k_λ^{*} =0.2, $K_1^{*} = \upsilon_0^{*}$ = 1.0.

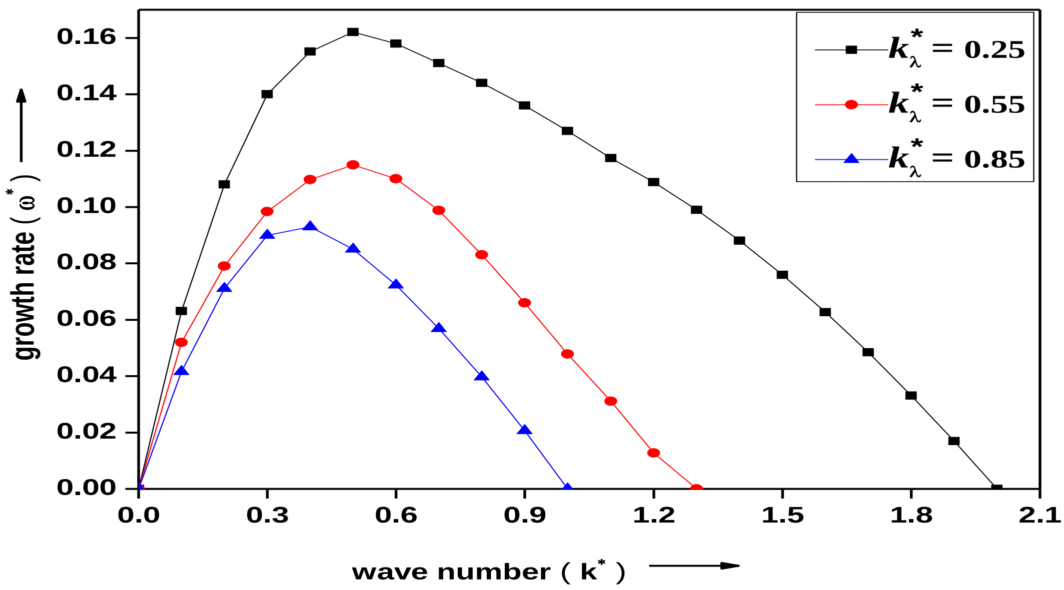

Fig. 5. The normalized growth rate (ω^*) as a function of normalized wave number (k^*) for different values of k_λ^* with k_T^* = 0.5 and $K_1^* = \upsilon_0^* = \nu^* = 1.0$.

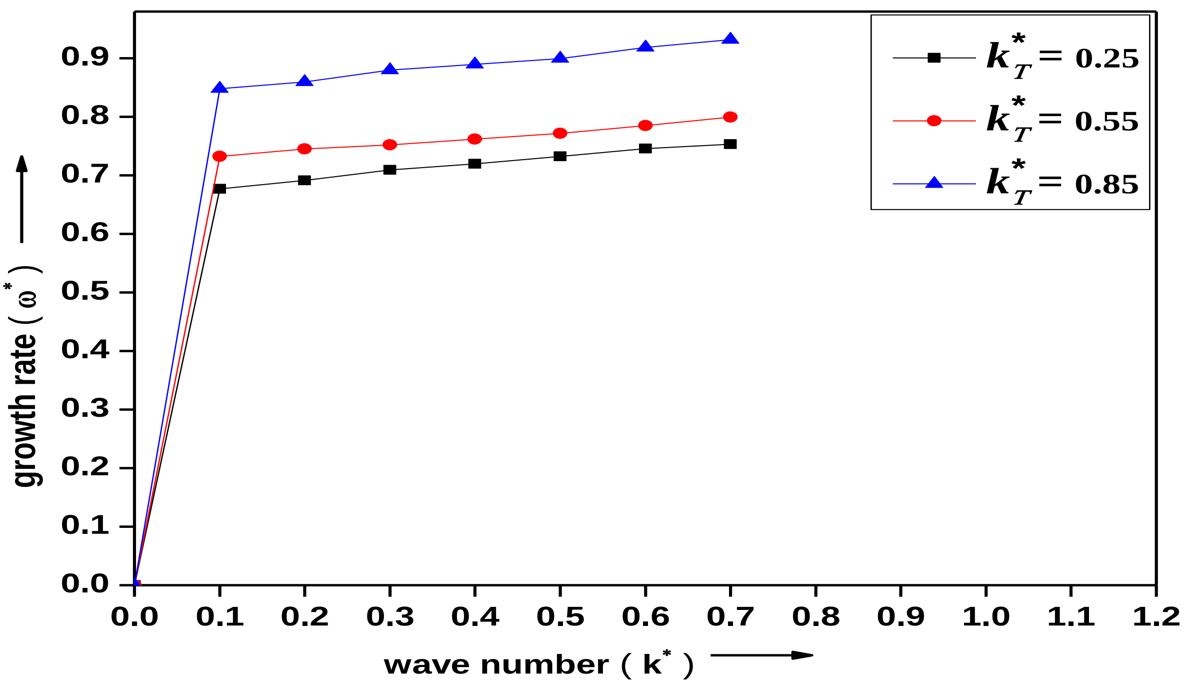

Fig. 6. The normalized growth rate (ω^*) as a function of normalized wave number (k^*) for different values of k_T^* with k_λ^* = 0.2 and $K_1^* = \upsilon_0^* = \nu^* = = 1.0$.

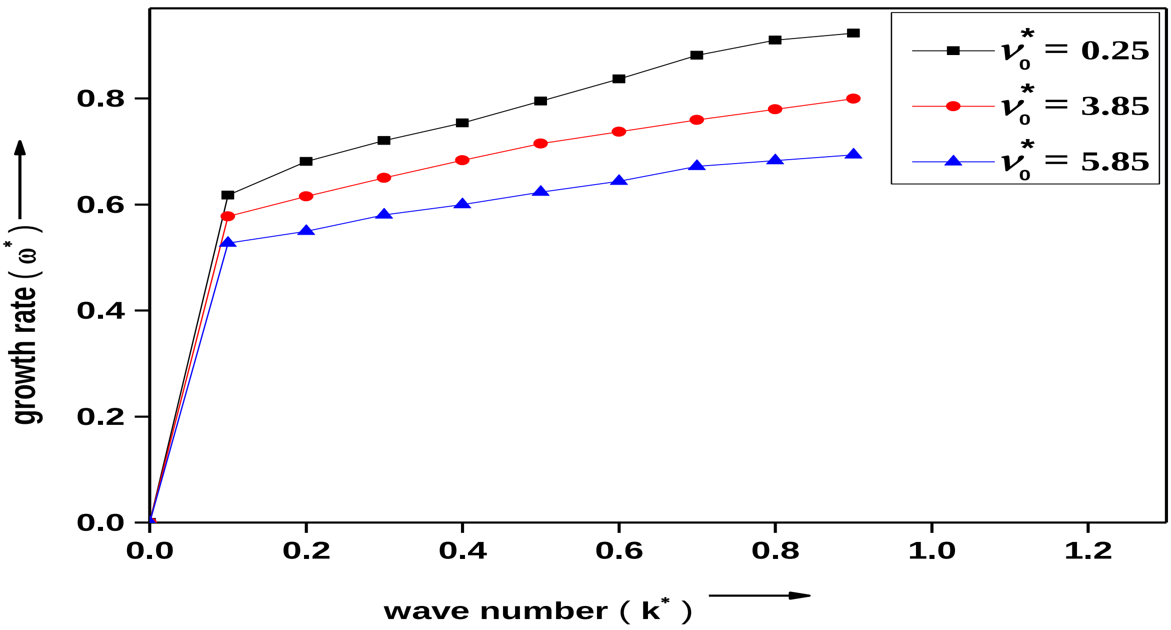

Fig. 7. The normalized growth rate (ω^*) as a function of normalized wave number (k^*) for different values of υ_0^* with k_λ^* = 0.2, k_T^* = 0.3 and $K_1^* = \nu^* = 1.0$.

From Fig. 6 we terminate that expansion rate decline with growing parameter k_T^*.Thus the presence of k_T^* become constant the development pace of the organization. Fig. 7 exhibits the authority of FLR corrections on the development pace of thermal instability. From figure it is understandable that the FLR correction has a become constant effect on the enlargement pace of thermal instability. Therefore, the limitation viscosity, radiative heat-loss functions and FLR corrections have steady authority on the arrangement.

For non-viscous, radiating, thermally conducting, magnetized, finitely conducting, medium with FLR corrections ($\upsilon = 0,\ L_{T,\rho} = V = \lambda = \upsilon_0 \neq 0$) equation (41) becomes

$$\omega^3 + \left\{(\gamma-1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right)\right\}\omega^2 + \left\{V^2k^2 + \upsilon_0^2 k^4 + c^2k^2\right\}\omega + \left\{\upsilon k\left[(\gamma-1)\left(\frac{T\rho L}{p} + \frac{\lambda k T}{p}\right)\right]\right.$$

$$\left. + V^2k^2(\gamma-1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right) + \left[k^2(\gamma-1)\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho}\right)\right]\right\} = 0. \qquad (45)$$

The above equation is adapted form of Vaghela and Chhajlani (1989) by inclusion of radiative heat-loss function. When constant term of equation (45) is less than zero this agree to at least one positive real root which communicates to the instability of the organization. The condition of instability attained from steady term of equation (45) is given as

$$\left\{k^2\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho}\right)\right\} < 0. \qquad (46)$$

From the above situation of instability given by equation (46) we finish that FLR corrections try to become stable the system. Also on contrast equations (41) and (46) we see that enclosure of viscosity take away the effects of FLR corrections and medium from circumstance of instability. So in both the holders either the organization is viscous or non-viscous, FLR corrections and steadies the growth rate of thermal instability.

For in viscid, thermally non-conducting, radiating, magnetized, finitely conducting, medium with FLR corrections $(\upsilon = \lambda = 0,\ L_{T,\rho} = V = \upsilon_0 \neq 0)$ equation (41) becomes

$$\omega^3 + \left(\frac{\gamma L_T}{c_p}\right)\omega^2 + \left(V^2k^2 + \upsilon_0^2 k^4 + c^2k^2\right)\omega + \left\{\upsilon_0^2 k^4\left(\frac{\gamma L_T}{c_p}\right) + V^2k^2\frac{\gamma L_T}{c_p}\right.$$

$$\left. + \frac{\gamma}{c_p}\left[k^2\left(c'^2 L_T - \frac{pL_\rho}{T}\right)\right]\right\}\omega = 0. \qquad (47)$$

When steady expression of equation (47) is a smaller amount than zero this consent to at least one positive real root which communicates to the instability of the organization. The condition of instability gained from steady expression of equation (47) is given as

$$\left\{k^2\left(c'^2 - \frac{pL_\rho}{TL_T}\right)\right\} < 0, \qquad (48)$$

For in viscid, infinitely conducting, radiating, thermally conducting, magnetized, porous medium with FLR corrections ($\upsilon = 0,\ L_{T,\rho} = V = \lambda = \upsilon_0 \neq 0$) equation (41) becomes

$$\omega^2 + \left\{(\gamma-1)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right)\right\}\omega + \left\{V^2k^2 + \upsilon_0^2k^4 + c^2k^2\right\} + \left\{\left(\upsilon_0^2k^4 + V^2k^2\right)(\gamma-1)\right.$$

$$\left. + \left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right) + k^2(\gamma-1)\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho}\right)\right\} = 0. \qquad (49)$$

When steady term of equation (49) is not as much of as zero this permits at least one positive real root which communicates to the instability of the arrangement. The circumstance of instability attained from invariable term of equation (49) is given as

$$\left\{\left(\upsilon_0^2k^4 + V^2k^2\right)\left(\frac{T\rho L_T}{p} + \frac{\lambda k^2 T}{p}\right) + k^2\left(TL_T - \rho L_\rho + \frac{\lambda k^2 T}{\rho}\right)\right\} < 0. \qquad (50)$$

The above circumstance of instability (50) is the tailored form of equation (41) of Prajapati et al., 2010 by and FLR corrections, exclusive of electron inertia in their case. From the circumstance of instability prearranged by equation (50) we bring to a close that, FLR corrections and magnetic field try to stabilize the system. Also on comparing equations (41) and (49) we see that inclusion of viscosity remove the effect of FLR corrections, and magnetic field from circumstance of instability. So in both the cases whether the system is viscous or non-viscous FLR corrections become stable the enlargement pace of thermal instability.

Thus we conclude that FLR corrections, heat-loss function, thermal conductivity, magnetic field strength and viscosity have stabilizing influence on the augmentation pace of thermal instability,

6. Conclusion

In the in attendance difficulty we have deliberate the consequences of permeability FLR corrections on the thermal instability of infinite homogeneous viscous plasma with thermal conductivity, radiative heat-loss function, permeability. The general dispersion relation is obtained which is modified due to the presence of considered physical parameters and is discussed for longitudinal and transverse mode of propagation to the direction of magnetic field. We find that the basic principle of thermal instability regarding the size of initial break up is significantly modified due to radiative heat-loss function, and FLR corrections. The effect of heat-loss function parameters is found to stabilize the system in both the longitudinal mode and transverse mode of propagation.

In the case of longitudinal mode of propagation, we find Alfven mode customized by the attendance of permeability, FLR corrections and viscosity. The thermal mode is obtained separately which is modified by the presence of permeability, radiative heat-loss function, thermal conductivity and viscosity. The condition of thermal instability is unaffected by the presence FLR corrections, permeability and viscosity. From the curves we find that the heat-loss function has a steady position on the growth rate of the organization in longitudinal mode of propagation.

In the container of transverse method of propagation, we acquire a thermal manner customized by the attendance of permeability, FLR corrections, radiative heat-loss function, thermal conductivity and viscosity. We find that the condition of instability is independent of FLR corrections and viscosity, and depends only on thermal conductivity and radiative heat-loss function. But the growth rate is pretentious by the attendance of all the measured limitations. For the case of inviscid and thermally non-conducting medium it is found that the condition of instability modified due to the presence of FLR corrections and radiative heat-loss function. It is experimental that for an inviscid medium the condition of instability is modified due to the presence of FLR corrections, magnetic field, thermal conductivity and radiative heat-loss function, and it is sovereign of permeability and viscosity. From the curves we discover that the heat-loss function has become constant effect on the enlargement pace of thermal instability. Also it is interesting to see that in both the cases the peak value of the curves decreases on growing heat-loss meaning these earnings that the organization becomes more constant on raising the value of heat-loss function. The consequence of FLR corrections is to become stable the organization.

Whilst the cloud density arrives at dangerous value, the cloud fragments into chilly dense condensations via thermal instability. When the serious density augment as metallicity diminish, and also as radiation augment. Condensations have a collision with each other and self-gravitating clumps will be shaped when the denote cloud density becomes adequately elevated; then stars will appearance. Development of the H II region in the region of the enormous star and supernova explosions will gust rotten neighboring gas and conclusion star arrangement development. When the denote density at the time of star structure is elevated, towering virial velocity stop development of the H II region. Also, in such high-density environments, the star configuration timescale is smaller than the lifetime of an enormous star. Then the gas in cluster-forming district will be rehabilitated into stars efficiently, before the gas is disconnected by get beggaring H II region or supernova explosions. High density is comprehended in the constricting low-metallicity gas, and if the configuration of a contracting gas cloud is probable, a physically powerful radiation situation is one more contender. Thus, it is not compulsory that far above the ground star configuration efficiency and jump cluster configuration are predictable attained in low-metallicity and/or strong-radiation surroundings. Such surroundings survives in dwarf galaxies, the near the beginning phase of our Galaxy and starburst galaxies.

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References

Aggrawal, Talwar, 1969 - *Aggrawal, M. and Talwar, S.P.,* (1969) Magnetothermal instability in a rotating gravitating fluid, *Mon. Not. R. Astron. Soc.*, vol. 146, pp. 235-242.

Bhatia, Chhonkar, 1985 - *Bhatia, P.K. and Chhonkar, R.P.S.,* (1985) Larmor radius effects on the instability of a rotating layer of a self-gravitating plasma, *Astrophys. Space Sci.*, vol. 115, pp. 327-344.

Bora, Talwar, 1993 - *Bora, M.P. and Talwar, S.P.,* (1993) Magnetothermal instability with generalized Ohm's law, *Phys. Fluids B*, vol. 5, pp. 950-955.

Choudhary, Sharma, 2016 - *Choudhary, P.P. & Sharma, P.,* (2016) Cold gas in cluster cores: global stability analysis and non-linear simulations of thermal instability, *Mon. Not. R. Astron. Soc.*, vol. 457, pp. 2554-2567.

Ferraro, 2007 - *Ferraro, N.M.,* (2007) Finite Larmor radius effects on the magnetorotational instability, *Astrophys. J.*, vol. 662, pp. 512-516.

Field, 1965 - *Field, G.B.,* (1965) Thermal instability, *Astrophys. J.*, vol.142, pp. 531-567.

Goldsmith, Habing, 1970 - *Goldsmith, D. W. & Habing,* (1970) Thermal stability and equilibrium–the two-phase ISM model of field, *Astrophys. J.*, vol. 161, p. 42.

Herrnegger, 1972 - *Herrnegger, F.,* (1972) Effects of collisions and gyroviscosity on thermal instability in a two-component plasma, *J. Plasma Phys.*, vol. 8, pp. 393-400.

Hobbs et al., 2013 - *Hobbs, A., Read, J., Power, C. & Cole, D.,* (2013) Thermal instability in cooling galactic coronae: fuelling star formation in galactic discs, *Mon. Not. R. Astron. Soc.*, vol. 434, pp. 1849-1868.

Hunter, 1970 - *Hunter, J.H., Jr.* (1970) Generalized thermal stability and its application for interstellar medium, *Astrophys. J.*, vol. 161, pp. 451-455.

Hunter, 1971 - *Hunter, J.H., Jr.* (1971) Generalized thermal stability and its application for interstellar medium, *Astrophys. J.*, vol. 166, pp. 451-453.

Iabnez, Sancher, 1992 - *Iabnez, M.H. & Sancher, N.M.,* (1992) Propagation of sound and thermal waves in a plasma with solar abundance, *Astrophys. J.*, vol. 396, pp. 717-724.

Ibanez, 1985 - *Ibanez, M.H.S.,* (1985) Sound and thermal waves in a fluid with an arbitrary heat-loss function, *Astrophys. J.*, vol. 290, pp. 33-46.

Jeffery, Taniuti, 1966 - *Jeffery, A. and Taniuti, T.,* (1966) MHD *Stability and Thermonuclear Containment*, Academic Press, New York.

McCray, Stien, 1975 - *McCray, R. & Stien, R.F.,* (1975) Thermal instability in superova shells, *Astrophys. J.*, vol. 196, pp. 565-570.

Najad-Asghar, 2007 - *Najad-Asghar, M.,* (2007) Formation of fluctuations in a molecular slab via isobaric thermal instability, *Mon. Not. R. Astron. Soc.*, vol. 379, pp. 222-228.

Najad-Asghar, Ghanbari, 2003 - *Najad-Asghar, M. & Ghanbari, J.* (2003) Linear thermal instability and formation of clumpy gas clouds including the ambipolar diffusion, vol. 345, pp. 1323-1328.

Najad-Asghar, Ghanbari, 2006 - *Najad-Asghar, M. and Ghanbari, J.,* (2006) Formation of small-scale condensations in the molecular clouds via thermal instability, *Astrophys. Space Sci.*, vol. 302, pp. 243-251.

Nipotic, 2010 - *Nipotic, C.,* (2010) Thermal instability in rotating galactic coronae, *Mon. Not. R. Astron. Soc.*, vol. 406, pp. 247-263.

Nipoti, Posti, 2013 - *Nipoti, C. & Posti, L.,* (2013) Thermal stability of a weakly rotating plasma, *Mon. Not. R. Astron. Soc.*, vol. 428, pp. 815-827.

Nusel, 1986 - *Nusel, P.E.J.,* (1986) Thermal instability in cooling flows, *Mon. Not. R. Astron. Soc.*, vol. 133, pp. 239-245.

Panavano, 1988 - *Panavano, A.,* (1988) Self-regulating star formation in isolated galaxies: thermal instability in the interstellar medium, *Astron. Astrophys.*, vol. 205, pp. 71-76.

Pikel'ner, 1968 - *Pikel'ner, S.B.,* (1968) Heating of interstellar gas by sub-cosmic rays formation of clouds, *Soviet Astron.*, vol. 11. p. 737.

Prajapati et al., 2010 - *Prajapati, R.P., Pensia, R.K., Kaothekar, S. and Chhajlani, R.K.,* (2010) Self-gravitational instability of rotating viscous Hall plasma with arbitrary radiative heat-loss functions and electron inertia, *Astrophys. Space Sci.*, vol. 327, pp. 139-154.

Roberts, Taylor, 1962 - *Roberts, K.V. and Taylor, J.B.,* (1962) Magnetohydrodynamic equations for finite Larmor radius, *Phys. Rev. Lett.*, vol. 8, pp. 197-198.

Szunzkiewicz, Millar, 1997 - *Szunzkiewicz, E. & Millar, J.C.,* (1997) On the thermal stability of transonic accretion discs, *Mon. Not. R. Astron. Soc.*, vol. 387, pp. 165-179.

Shadmehri, Dib, 2009 - *Shadmehri, M. and Dib, S.,* (2009) Magnetothermal condensation modes including the effects of charged dust particles, *Mon. Not. R. Astron. Soc.*, vol. 395, pp. 985-990.

Sharm, Prakash, 1975 - *Sharm, R.C., & Prakash, K.,* (1975) Radiative transfer and collisional effects on thermal convective instability of a composit medium, *Progress of Theoretical Physics*, vol. 54, pp. 409-414.

Stiele et al., 2006 - *Stiele, H., Lesch, H. and Heitsch, F.,* (2006) Thermal instability in a weakly ionized plasma, *Mon. Not. R. Astron. Soc.*, vol. 372, pp. 862-868.

Vaghela, Chhajlani, 1989 - *Vaghela, D.S. and Chhajlani, R.K.,* (1989) Magnetothermal stability of resistive plasma through porous medium with thermal conduction and FLR corrections, *Contrib. Plasma Phys.*, vol. 29, pp. 77-89.

Vasiliev, 2012 - *Vasiliev, E.O.,* (2012) Thermal instability in a collisionally cooled gas, *Mon. Not. R. Astron. Soc.*, vol. 419, pp. 3641-3648.

Vandakurov, 1964 - *Vandakurov, Iu.V.,* (1964) On the theory of stability of a plasma in a strong longitudinal magnetic field, variable along the axis of symmetry, *Prikl. Mat. Mekh.*, vol. 28, pp. 77-89, 1964.

Wolfire et al, 1995 - *Wolfire, M. G., Hollenbach, D., Mckee, C. F., Tielens, A.G.G.M., & Bakes, E.L.O.,* (1995) The neutral atomic phases of the interstellar medium, *Astrophys. J.*, vol. 443, pp. 152-168.