



## Jeans' Gravitational Instability of Rotating Plasma

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abstract

The gravitational instability of infinitely extending homogeneous rotating plasma permeated by an oblique magnetic field is considered. The solution has been obtained through the normal mode technique and dispersion relation has been derived. It is shown that Jeans' criterion remains unchanged in the present problem. The dispersion relation obtained has been solved numerically and it has been found that the Coriolis forces and viscosity have a stabilizing influence while Hall current and magnetic resistivity have destabilizing influence on the growth rate of the unstable mode of disturbance.

### I. INTRODUCTION

The gravitational instability problem of an infinite homogenous medium was first considered by Jeans [1]. According to Jeans' criterion, an infinite homogenous self-gravitating atmosphere is unstable for all wave numbers  $k$  smaller than the Jeans' wave number  $k_j = \sqrt{G\rho}/S$ , where  $\rho$  is the density,  $G$  the gravitational constant and  $S = \sqrt{kT/m}$  the velocity of sound in the gas,  $k$  the Boltzmann's constant,  $T$  the temperature and  $m$  the mass of the particle.

Since then, several researchers have studied this problem under varying assumptions of hydrodynamics and hydromagnetics. A comprehensive account of these investigations has been given by Chandrasekhar [2] in his monograph on hydrodynamic and hydromagnetic stability. Gliddon first considered the gravitational instability of infinitely extending isotropic plasma by using the Chew Goldberger-Low (CGL) [3] equations. He has shown that unlike the case of uniform plasma, the stability criterion is dependent upon magnetic field. Bhatia [4] has extended the study to the case of rotating isotropic plasma. It has been shown there that stability depends on both magnetic field and rotation. Bhatia [5] studied the influence of uniform rotation, Hall currents, finite conductivity and FLR on gravitational instability. The Hall Effect on plasma stability has been extensively examined (Khan and Bhatia [6] leading to the conclusion that the Hall currents are destabilizing in nature. Chhajlani and Vaghela [7] have studied the stability of self gravitating plasma with thermal conduction and Finite Larmor Radius (FLR) through porous medium. In all such investigations, carried out separately under varying assumptions, it was found that the condition of instability has been determined by the Jeans Criterion with some modifications, introduced by the inclusion of the various parameters.

In cosmic physics, there are several situations, such as chromospheres, the solar photosphere and cool interstellar clouds, where the plasmas are frequently not fully ionized but may instead be partially ionized, so that the interaction between the ionized fluid and the neutral gas becomes important. Research, considering the case of partially ionized plasmas has been carried out by Alfvén [8], Lehnert [9], Kumar

and Srivastava [10], Cadez [11], Ali and Bhatia [12]. Bhatia and Chowdhary [13] have studied the gravitational instability of rotating, thermally conducting unbounded plasma with the effects of Hall current, magnetic resistivity and viscosity in an oblique magnetic field.

In recent years, Jeans' stability problems have been analyzed in the framework of nonextensive Tsallis [14] statistics and its associated kinetic theory. Noteworthy work in this field has been done by Lima et al. [15], Du [16], [17] and Shaikh et al. [18], [19], [20], [21]. This paper deals with the study of the problem of the gravitational instability of viscous infinitely extending rotating plasma in presence of the Hall currents and finite conductivity. It is assumed that the plasma is permeated by an oblique magnetic field. The analysis is done in the non-relativistic regime.

## II. PERTURBATION EQUATIONS

We consider the motion of infinitely extending homogenous gravitating finitely conducting viscous rotating plasma in the presence of effects of Hall currents in the non-relativistic regime. The linearized perturbation equations governing the motion of such plasma rotating with uniform angular velocity  $\vec{\Omega}$  ( $\Omega_x, \Omega_y, \Omega_z$ ) are:

$$\rho \left[ \frac{\partial \vec{u}}{\partial t} + 2 (\vec{\Omega} \times \vec{u}) \right] = -\nabla \delta p + (\nabla \times \vec{h}) \times \vec{H} + \rho \nabla \delta \Phi + \mu \nabla \vec{u} + \frac{1}{3} \mu \nabla (\nabla \cdot \vec{u}), \quad (2.1)$$

$$\frac{\partial \vec{h}}{\partial t} = \nabla \times (\vec{u} \times \vec{H}) - \frac{1}{N_e} \nabla \times [(\nabla \times \vec{h}) \times \vec{H}] + \eta \nabla \vec{h}, \quad (2.2)$$

$$\frac{\partial}{\partial t} (\delta \rho) = -\rho (\nabla \cdot \vec{u}), \quad (2.3)$$

$$\nabla^2 \delta \phi = -G \delta \rho, \quad (2.4)$$

$$\delta p = S^2 \delta \rho. \quad (2.5)$$

Where  $\delta \rho$ ,  $\delta p$ ,  $\vec{u} (u, v, w)$ ,  $\vec{h} (h_x, h_y, h_z)$  and  $\delta \phi$  are perturbations in density  $\rho$ , pressure  $p$ , velocity, magnetic field  $\vec{H}$  and the gravitational potential  $\phi$ . We seek the solution of the equations (2.1) - (2.5) whose dependence on  $x, z$  and time  $t$  is given by:

$$\exp (ik \sin \theta x + ik \cos \theta z + int), \quad (2.6)$$

where  $\vec{k} = (k \sin \theta, 0, k \cos \theta)$  is the wave number of perturbation making angle  $\theta$  with X-axis and  $n$  (may be complex) is the frequency of perturbation.

For the perturbation of the form (2.6), equations (2.1) - (2.5) give six equations governing the perturbation of velocity and magnetic field, which are:

$$\begin{aligned} & u \left\{ in + v k^2 \left( 1 + \frac{1}{3} \sin^2 \theta \right) - \frac{i}{n} M \sin^2 \theta \right\} - 2\Omega_z v \\ & + w \left\{ 2\Omega_y + \frac{1}{3} v k^2 \sin \theta \cos \theta - \frac{iM}{n} \sin \theta \cos \theta \right\} \\ & - \left( \frac{ik H_z}{\rho} \right) \cos \theta h_x + \left( \frac{ik H_z}{\rho} \right) \sin \theta h_z = 0, \end{aligned} \quad (2.7)$$

$$2\Omega_z u + v (in + vk^2) - 2\Omega_x w - \frac{ikN_1}{\rho} h_y = 0, \tag{2.8}$$

$$u \left\{ \frac{vk^2}{3} \sin \theta \cos \theta - \frac{iM}{n} \sin^2 \theta - 2\Omega_y \right\} + 2\Omega_x v$$

$$+ w \left\{ in - \frac{iM}{n} \sin \theta \cos \theta + vk^2 \left( 1 + \frac{1}{3} \cos^2 \theta \right) \right\} + \frac{ikH_x}{\rho} \cos \theta h_x$$

$$- \frac{ikH_x}{\rho} \sin \theta h_z = 0, \tag{2.9}$$

$$(-ikH_z) \cos \theta u + (ikH_x) \cos \theta w + (in + \eta k^2) h_x + \left( \frac{k^2 N_1}{Ne} \right) \cos \theta h_y = 0, \tag{2.10}$$

$$(-ikN_1) v + (N_1 \cos \theta) h_x + (in + \eta k^2) h_y + \left( \frac{k^2 N_1}{Ne} \right) \sin \theta h_z = 0, \tag{2.11}$$

$$(ikH_z) \sin \theta u - (ikH_x) \sin \theta w - \left( \frac{k^2 N_1}{Ne} \right) \sin \theta h_y + (in + \eta k^2) h_z = 0. \tag{2.12}$$

These six equations (2.7)-(2.12) can be written in the matrix form as:

$$[A][B] = 0, \tag{2.13}$$

where  $[B]$  is the single column matrix whose elements are  $u, v, w, h_x, h_y$  and  $h_z$  and  $[A]$  is the sixth order matrix whose elements are:

$$A_{11} = \left[ in - \frac{i}{n} M \sin^2 \theta + vk^2 \left( 1 + \frac{1}{3} \sin^2 \theta \right) \right], A_{12} = -2\Omega_z,$$

$$A_{13} = \left[ 2\Omega_y + \left( \frac{-iM}{n} + \frac{1}{3} vk^2 \right) \sin \theta \cos \theta \right], A_{14} = \frac{1}{\rho} (ikH_z) \cos \theta,$$

$$A_{15} = 0, A_{16} = \frac{1}{\rho} (ikH_z) \sin \theta,$$

$$A_{21} = 2\Omega_z, A_{22} = (in + vk^2), A_{23} = -2\Omega_x, A_{24} = 0,$$

$$A_{25} = \frac{-1}{\rho} (ik) N_1, \quad A_{26} = 0,$$

$$A_{31} = \left[ -2\Omega_y + \left( \frac{-iM}{n} + \frac{1}{3} k^2 v \right) \sin \theta \cos \theta \right], A_{32} = 2\Omega_x,$$

$$A_{33} = \left[ in - \frac{-iM}{n} \cos^2 \theta + vk^2 \left( 1 + \frac{1}{3} \cos^2 \theta \right) \right],$$

$$\begin{aligned}
 A_{34} &= \frac{1}{\rho} (ikH_x) \cos \theta, & A_{35} &= 0, & A_{36} &= \frac{-1}{\rho} (ikH_x) \sin \theta, \\
 A_{41} &= - (ikH_z) \cos \theta, & A_{42} &= 0, & A_{43} &= (ikH_x) \cos \theta, \\
 A_{44} &= (in + \eta k^2), & A_{45} &= \left( \frac{k^2 N_1}{Ne} \right) \cos \theta, & A_{46} &= 0, \\
 A_{51} &= 0, & A_{52} &= - (ikN_1), & A_{53} &= 0, \\
 A_{54} &= \frac{-k^2}{Ne} (N_1 \cos \theta), & A_{55} &= (in + \eta k^2), & A_{56} &= \frac{k^2}{Ne} (N_1 \sin \theta), \\
 A_{61} &= (ikH_z) \sin \theta, & A_{62} &= 0, & A_{63} &= - (ikH_x) \sin \theta, \\
 A_{64} &= 0, & A_{65} &= \frac{-k^2}{Ne} (N_1 \sin \theta), & A_{66} &= (in + \eta k^2).
 \end{aligned}$$

Where

$$M = (S^2 k^2 - G\rho),$$

$$N_1 = (H_x \sin \theta + H_z \cos \theta),$$

$v = \frac{\mu}{\rho}$  is the coefficient of kinematic viscosity.

### III. DISPERSION RELATION

The vanishing of  $|A|$  gives the dispersion relation as the product of two factors. The first factor gives:

$$in + \eta k^2 = 0 \tag{3.1}$$

which corresponds to viscous type of damped mode modified by finite conductivity, and the second factor gives

$$W_6 n^6 + W_5 n^5 + W_4 n^4 + W_3 n^3 + W_2 n^2 + W_1 n + W_0 = 0 \tag{3.2}$$

where

$$\begin{aligned}
 W_6 &= -i (\sin \theta + \cos^2 \theta) \\
 W_5 &= k^2 \left\{ \frac{10}{3} v \sin \theta + 2\eta \sin \theta + \frac{7}{3} v \cos^2 \theta + 2\eta \cos^2 \theta \right\} \\
 W_4 &= -i \left[ k^6 \left\{ 2v\eta \cos^2 \theta \right\} + k^4 \left\{ \begin{aligned} &\frac{11}{3} v^2 \sin \theta + \eta^2 \sin \theta + \frac{14}{3} (v\eta) \sin \theta \\ &+ \frac{5}{3} v^2 \cos^2 \theta + \eta^2 \cos^2 \theta + \frac{14}{3} (v\eta) \cos^2 \theta \\ &+ \frac{N_1^2}{(Ne)^2} \cos^4 \theta \end{aligned} \right\} \right. \\
 &\quad \left. + k^2 \left\{ \frac{N_1^2}{\rho} \cos^2 \theta + \frac{N_1^2}{\rho} \sin \theta + \frac{(H_x^2 + H_z^2)}{\rho} \cos^4 \theta \right\} \right. \\
 &\quad \left. + M (\sin \theta + \cos^2 \theta) + 8 (\Omega_x^2 + \Omega_z^2) \sin \theta + 4\Omega_y^2 \sin \theta \right. \\
 &\quad \left. + 2 (v\eta) \sin \theta + 4 \cos^2 \theta (\Omega_x^2 - \Omega_z^2) + 4\Omega_y^2 \cos^2 \theta \right]
 \end{aligned}$$

$$W_3 = - \left[ \begin{aligned} & k^8 \{ v^2 \eta \cos^2 \theta \} \\ & + k^6 \left\{ \frac{4}{3} v^3 \sin \theta + \frac{10}{3} \eta^2 (v \sin \theta) + 7 (v^2 \eta) \sin \theta + \frac{4}{3} v^3 \cos^2 \theta \right\} \\ & \quad + \frac{7}{3} (\eta^2 v) \cos^2 \theta + \frac{2}{3} (v^2 \eta) \cos^2 \theta + \frac{10}{3} v \frac{N_1^2}{(Ne)^2} \cos^4 \theta \left. \right\} \\ & + k^4 \left\{ \frac{2v}{\rho} (H_x^2 + H_z^2) \cos^4 \theta + \frac{1}{3} v \frac{N_1^2}{\rho} \cos^4 \theta + \frac{\eta}{\rho} (H_x^2 + H_z^2) \cos^4 \theta \right\} \\ & \quad + \frac{7}{3} \frac{v}{\rho} N_1^2 \cos^2 \theta + \frac{\eta}{\rho} N_1^2 \cos^2 \theta + \frac{7}{3} v \frac{N_1^2}{\rho} \sin \theta + \frac{\eta}{\rho} N_1^2 \sin \theta \left. \right\} \\ & + k^2 \left\{ \begin{aligned} & 2Mv \sin \theta + \frac{28}{3} v \sin \theta (\Omega_x^2 + \Omega_z^2) \\ & + \frac{8}{3} v \Omega_x \Omega_z (\sin^2 \theta \cos \theta) + 4\Omega_y^2 v \sin \theta \\ & + 2M\eta \sin \theta + 16\eta \sin \theta (\Omega_x^2 + \Omega_z^2) + 8\eta \Omega_y^2 \sin \theta + 2Mv \cos^2 \theta \\ & + 4v \cos^2 \theta (\Omega_x^2 - \Omega_z^2) + \frac{4}{3} v \cos^2 \theta (\Omega_z^2 \cos^2 \theta - \Omega_x^2 \sin^2 \theta) \\ & + 4v \Omega_y^2 \cos^2 \theta + 2M\eta \cos^2 \theta + 8\eta \cos^2 \theta (\Omega_x^2 - \Omega_z^2) + 8\eta \Omega_y^2 \cos^2 \theta \end{aligned} \right\} \\ & + 8\Omega_x \Omega_y \Omega_z \cos^2 \theta \end{aligned} \right]$$

$$W_2 = i \left[ \begin{aligned} & k^8 \left\{ \frac{4}{3} v^2 \eta \sin \theta + \frac{7}{3} v^2 \eta^2 \sin \theta + \frac{8}{3} v^3 \eta \sin \theta + \frac{1}{3} v^2 \eta^2 \cos^2 \theta \right\} \\ & \quad + \frac{8}{3} v^3 \eta \cos^2 \theta + \frac{11}{3} v^2 \frac{N_1^2}{(Ne)^2} \cos^4 \theta \left. \right\} \\ & + k^6 \left\{ \begin{aligned} & \frac{4}{3} v^2 \eta^2 \cos^2 \theta + \frac{v^2}{\rho} (H_x^2 + H_z^2) \cos^4 \theta + \frac{2}{3} \frac{v^2}{\rho} N_1^2 \cos^2 \theta \\ & + \frac{1}{3} \frac{v^2}{\rho} N_1^2 \cos^4 \theta + 2 \frac{v\eta}{\rho} (H_x^2 + H_z^2) \cos^4 \theta + \frac{1}{3} \frac{v\eta}{\rho} N_1^2 \cos^4 \theta \\ & + \frac{7}{3} \frac{v\eta}{\rho} N_1^2 (\cos^2 \theta + \sin \theta) + \frac{2}{3} \frac{v^2}{\rho} N_1^2 \sin \theta \\ & + \frac{4}{9} \frac{v^2}{\rho} N_1^2 \sin^3 \theta \cos^2 \theta \end{aligned} \right\} \\ & + k^4 \left\{ \begin{aligned} & M (v^2 + \eta^2) (\sin \theta + \cos^2 \theta) + 4\Omega_y^2 \eta^2 (\sin \theta + \cos^2 \theta) \\ & + 8\eta^2 \sin \theta (\Omega_x^2 + \Omega_z^2) + 4Mv\eta \sin \theta + \frac{54}{3} v\eta \sin \theta (\Omega_x^2 + \Omega_z^2) \\ & + \frac{16}{3} v\eta \Omega_x \Omega_z \sin^2 \theta \cos \theta + 8\Omega_y^2 v\eta \sin \theta + 4v^2 (\Omega_x^2 - \Omega_z^2) \cos^2 \theta \\ & + 4v\eta \cos^2 \theta \\ & + 8v\eta (\Omega_x^2 - \Omega_z^2) \cos^2 \theta + \frac{8}{3} v\eta \cos^2 \theta (\Omega_z^2 \cos^2 \theta - \Omega_x^2 \sin^2 \theta) \\ & + 4\Omega_y^2 v\eta \cos^2 \theta + \frac{MN_1^2}{(Ne)^2} \cos^4 \theta + \frac{N_1^2}{\rho^2} (H_x^2 + H_z^2) \cos^4 \theta \end{aligned} \right\} \\ & + k^2 \left\{ \begin{aligned} & 16\eta \Omega_x \Omega_y \Omega_z \cos^2 \theta + \frac{MN_1^2}{\rho} (\cos^2 \theta (1 + \cos^2 \theta) + \sin \theta) \\ & + \frac{4(\Omega_x^2 H_x^2 + \Omega_z^2 H_z^2)}{\rho} \cos^4 \theta + \frac{8}{\rho} (\Omega_x \Omega_z) H_x H_z \cos^4 \theta \\ & + 4\Omega_y^2 \frac{N_1^2}{\rho} (\cos^4 \theta + \sin \theta) \end{aligned} \right\} \\ & + 4M \sin \theta (\Omega_x^2 + \Omega_z^2) + 8M\Omega_x \Omega_z \sin^2 \theta \cos \theta \\ & + 4M \cos^2 \theta (\Omega_z^2 \cos^2 \theta - \Omega_x^2 \sin^2 \theta) \end{aligned} \right]$$

$$W_1 = \left[ \begin{aligned} & k^{10} \left\{ \frac{4}{3} v^3 \eta^2 (\cos^2 \theta + \sin \theta) + \frac{4}{3} v^3 \frac{N_1^2}{(Ne)^2} \cos^4 \theta \right\} \\ & + k^8 \left\{ \begin{aligned} & \frac{1}{3} v^2 \eta \frac{N_1^2}{\rho} \cos^4 \theta + \frac{v^2 \eta}{\rho} (H_x^2 + H_z^2) \cos^4 \theta + \frac{2}{3} (v^2 \eta) \frac{N_1^2}{\rho} (\cos^2 \theta + \sin \theta) \\ & + \frac{4}{9} v^2 \eta \frac{N_1^2}{\rho} \sin^3 \theta \cos^2 \theta \end{aligned} \right\} \\ & + k^6 \left\{ \begin{aligned} & 2Mv\eta^2 (\cos^2 \theta + \sin \theta) + \frac{28}{3} (v\eta^2) (\Omega_x^2 + \Omega_z^2) \sin \theta \\ & + \frac{8}{3} (v\eta^2) \Omega_x \Omega_z \sin^2 \theta \cos \theta + 4\Omega_y^2 v\eta^2 (\cos^2 \theta + \sin \theta) \\ & + 2Mv^2 \eta (\cos^2 \theta + \sin \theta) + 4v\eta^2 (\Omega_x^2 - \Omega_z^2) \cos^2 \theta \\ & - \frac{4}{3} v\eta^2 \cos^2 \theta (\Omega_z^2 \cos^2 \theta - \Omega_x^2 \sin^2 \theta) + 2Mv \frac{N_1^2}{(Ne)^2} \cos^4 \theta \\ & + 4\Omega_y^2 v \frac{N_1^2}{(Ne)^2} \cos^4 \theta + \left( \frac{N_1^2}{\rho^2} v \right) (H_x^2 + H_z^2) \cos^4 \theta + \frac{1}{3} \left( \frac{N_1^4}{\rho^2} v \right) \cos^4 \theta \end{aligned} \right\} \\ & + k^4 \left\{ \begin{aligned} & 8\eta^2 \Omega_x \Omega_y \Omega_z \cos^2 \theta + \frac{MN_1^2}{\rho} \eta \cos^2 \theta (1 + \cos^2 \theta) + 4\Omega_y^2 \eta \frac{N_1^2}{\rho} (\sin \theta + \cos^2 \theta) \\ & + \frac{MN_1^2}{\rho} \eta \sin \theta - \frac{2}{3} (Mv) \frac{N_1^2}{\rho} \sin^3 \theta \cos^2 \theta \end{aligned} \right\} \\ & + k^2 \left\{ \begin{aligned} & 8M\eta (\Omega_x^2 + \Omega_z^2) \sin \theta + 16M\eta (\Omega_x \Omega_z) \sin^2 \theta \cos \theta \\ & - 4M\eta \cos^2 \theta (\Omega_z^2 \cos^2 \theta - \Omega_x^2 \sin^2 \theta) \end{aligned} \right\} \end{aligned} \right]$$

$$W_0 = k^4 \left( \frac{5}{3} \frac{MN_1^2}{\rho} v \sin \theta \right) - i \left[ \begin{array}{l} k^8 \left\{ Mv^2\eta^2 (\sin \theta + \cos^2 \theta) + \frac{MN_1^2}{(Ne)^2} v^2 \cos^4 \theta \right\} \\ + k^6 \left\{ \frac{MN_1^2}{\rho} v\eta \sin \theta + \frac{2}{3} \frac{MN_1^2}{\rho} v\eta \sin^3 \theta \cos^2 \theta \right\} \\ + k^4 \left\{ \begin{array}{l} 4M\eta^2 (\Omega_x^2 + \Omega_z^2) \sin \theta + 8M\eta^2 \Omega_x \Omega_z \sin^2 \theta \cos \theta \\ + 4M\eta^2 \cos^2 \theta (\Omega_x^2 \sin^2 \theta - \Omega_z^2 \cos^2 \theta) \\ + 4M (\Omega_x^2 + \Omega_z^2) \frac{N_1^2}{(Ne)^2} \cos^4 \theta + \frac{MN_1^4}{\rho^2} \cos^4 \theta \end{array} \right\} \\ + k^2 \left\{ 8 \frac{MN_1^2}{(Ne)^2} \Omega_x \Omega_z \sin \theta \cos^5 \theta \right\} \end{array} \right]$$

IV. DISCUSSION

When M<0 equation (3.2) has always one negative real root. Hence there is always an unstable mode of wave propagation, when M<0. However, when M>0, the equation (3.2) has either all positive real roots or positive real roots and pair of complex conjugate roots. The real roots correspond to stable mode. If the roots are complex, Re(n) turns out to be one which has its coefficient alternately positive and negative implying thereby stability. Hence Jeans' criterion remains unchanged in this case.

In order to study the influence of various physical parameters on the growth rate of unstable mode, we have performed numerical calculation of the dispersion relation (3.2) (after making it non-dimensional) to locate the roots of n against k (wave number) for several values of the parameters. For these calculations we take the numerical values corresponding to the conditions in the galaxies for several values of parameters

$$\rho = 1.7 \times 10^{-21} Kg m^{-3}, G = 6.658 \times 10^{-11} (Kg)^{-1} m^3 s^{-2}$$

$$S^2 = 2.5 \times 10^8 m^2 s^{-2} V^2 = 5.0 \times 10^8 m^2 s^{-2}$$

The value of the critical wave length for the gravitational instability of a homogeneous infinitely extending fluid is of order of 10<sup>20</sup>m.

We have therefore calculated the roots of the dispersion relation (3.2) for different values of parameters namely, rotation (Ω), viscosity (ν), finite conductivity (η) and Hall current (Ne). These calculations are presented in Figures 1-6, where we have presented the growth rate (negative real root after multiplying by 10<sup>4</sup>) against wave number k (after multiplying by 10<sup>20</sup>) for Ω<sub>x</sub>=1.5, 2.5, 3.5, Ω<sub>y</sub>=0.5, 1.5, 2.5, Ω<sub>z</sub>=0.2, 1.2, 2.2, ν =2.0, 3.0, 4.0, η=0.1, 2.1, 4.1 and Ne=0.2, 2.2, 4.2 for θ=30°.

In figures 1-3, we plot the growth rate (positive real part of n) against wave number for parameter rotation Ω<sub>x</sub>, Ω<sub>y</sub> and Ω<sub>z</sub> respectively taking fixed values of H<sub>x</sub>=1, H<sub>z</sub>=1.5, ν = 0.1, η=0.8, Ne=0.2. We see that as rotation (Ω<sub>x</sub>, Ω<sub>y</sub> and Ω<sub>z</sub>) increases, growth rate n decreases indicating that the influence of rotation is stabilizing.

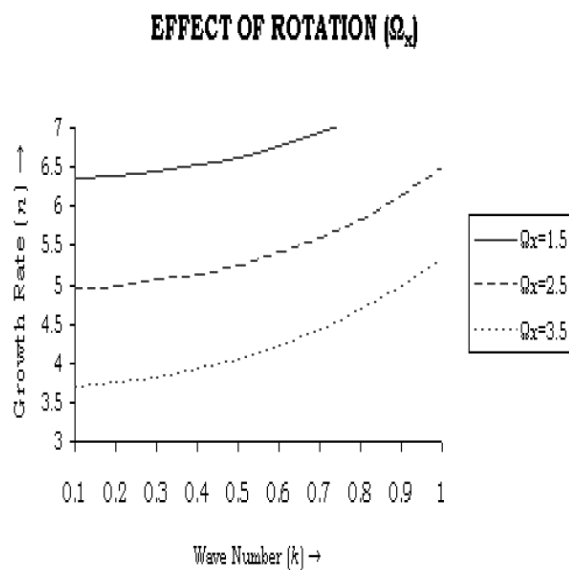


FIG. 1. Variation of Growth rate (n) against the wave number k for different values of rotation taking  $H_x = 1, H_z = 1.1, \nu = 0.1, \eta = 0.8, N_e = 0.2, \theta = 30^\circ$

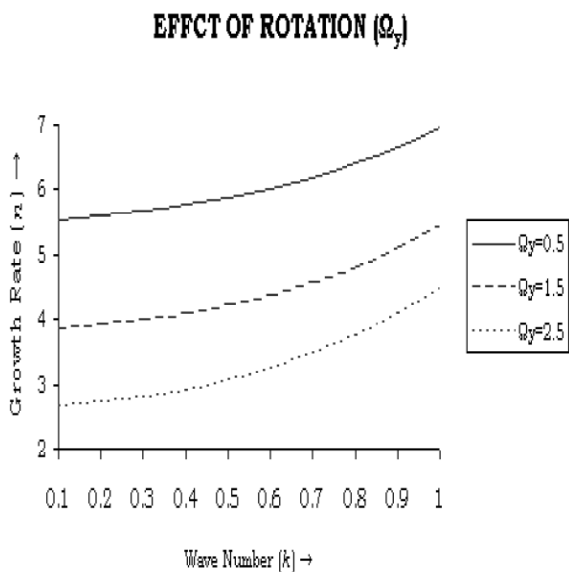


FIG. 2. Variation of Growth rate (n) against the wave number k for different values of rotation taking  $H_x = 1, H_z = 1.1, \nu = 0.1, \eta = 0.8, N_e = 0.2, \theta = 30^\circ$

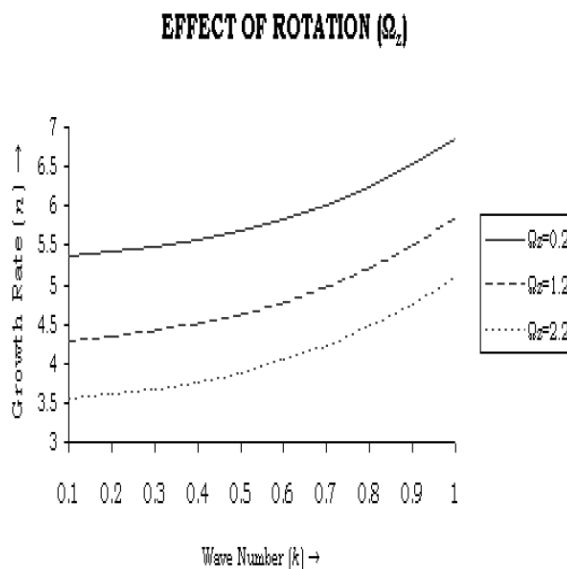


FIG. 3. Variation of Growth rate ( $n$ ) against the wave number  $k$  for different values of rotation taking  $H_x = 1, H_z = 1.1, \nu = 0.1, \eta = 0.8, N_e = 0.2, \theta = 30^\circ$

In figure 4, we plot the growth rate  $n$  (positive real part of  $n$ ) against wave number  $k$  for parameter viscosity  $\nu = 2.0, 3.0, 4.0$ , taking  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \eta =0.8, N_e=0.2$ . It is clearly seen that as viscosity ( $\nu$ ) increases growth rate ( $n$ ) decreases for same  $k$ , showing stabilizing character of viscosity.

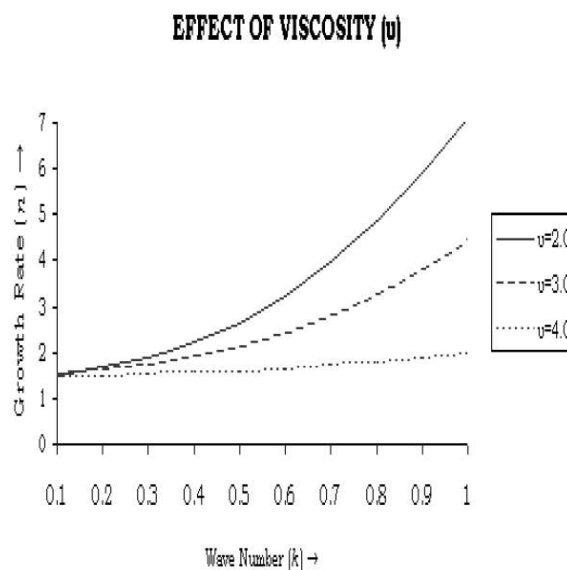


FIG. 4. Variation of Growth rate ( $n$ ) against the wave number  $k$  for different values of viscosity taking  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \eta =0.8, N_e=0.2, \theta = 30^\circ$

In figures 5, we have given the variation of growth rate  $n$  (positive real part of  $n$ ) against wave number  $k$  for the values of magnetic resistivity  $\eta=0.1, 2.1, 4.1$  for fixed  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \nu = 0.8, Ne=0.2$ . We see that as magnetic resistivity increases growth rate increases showing thereby destabilizing character of finite conductivity.

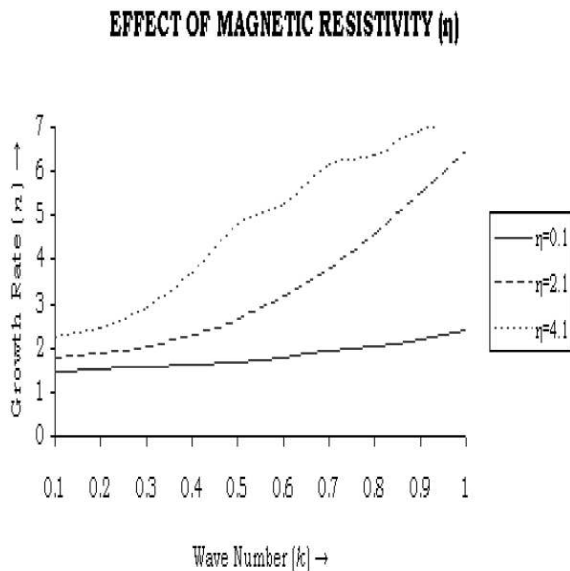


FIG. 5. Variation of Growth rate (n) against the wave number k for different values of magnetic resistivity taking  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \nu = 0.8, Ne=0.2, \theta = 30^\circ$

Figures 6, depicts the variation of growth rate with  $Ne=0.2, 2.2, 4.2$  for fixed  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \nu = 0.8, \eta=0.5$ . From figure 6, we see that growth rate increases as Hall current ( $Ne$ ) increases indicating that the influence of Hall current is destabilizing.

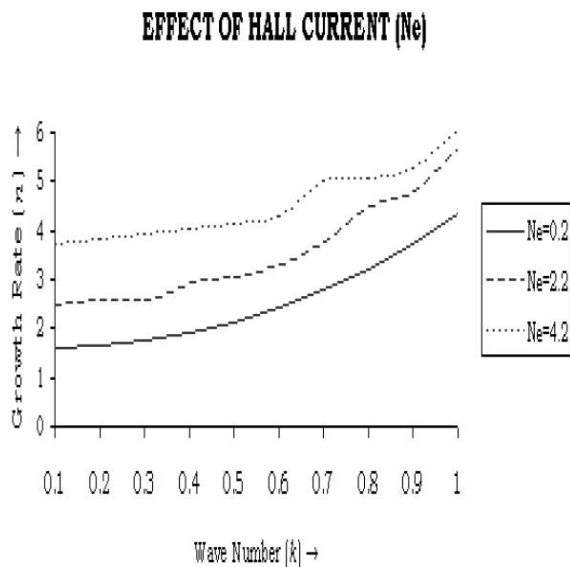


FIG. 6. Variation of Growth rate (n) against the wave number k for different values of hall Current taking  $H_x=1, H_z=1.1, \Omega_x= 1.1, \Omega_y= 1.5, \Omega_z= 1.0, \nu = 0.8, \eta=0.5, \theta = 30^\circ$

We therefore, conclude that the gravitational instability of an infinite homogeneous rotating fluid is still determined by Jeans' criterion when the effects of Hall currents and magnetic resistivity are included and when the fluid is permeated by an oblique magnetic field.

## Acknowledgments

This work was carried out as part of a major research project (**F. No. 36-103/2008 (SR)**) awarded by University Grants Commission (UGC), India to the one of the author **Aiyub Khan**. The financial assistance from UGC is gratefully acknowledged. The authors are grateful to the referee for useful suggestions, which have helped in improving the presentation and quality of the paper.

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