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THE ROLE OF CORIOLIS FORCE AND SUSPENDED PARTICLES IN THE FRAGMENTATION OF MATTER IN THE CENTRAL REGION OF GALAXY

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ABSTRACT

The role of Coriolis force and suspended particles in the fragmentation of matter in the central region of galaxy have been studied. A general dispersion relation is obtained with the help of linearized relevant magnetohydrodynamics (MHD) using normal mode analysis. It was found that an infinite homogenous viscous, permeability and suspended particles in the central region of galaxy with finite electrical resistivity and rotation is a stable system. The Coriolis force plays an important role in the central region of the galaxy.

Key words**:** Magnetohydrodynamics, Suspended particles, Viscosity rotation, Permeability, Electrical resistivity

INTRODUCTION

There has been a rapidly growing interest in understanding various collective process in gaseous plasma, which are ubiquitous in space, including diffuse and dense interstellar media, circumstellar shell, ionosphere, nova ejecta, star envelops, dark interiors molecular clouds, the out flow of red giant star and accretion has been found both theoretically and experimentally that, suspended particles, thermal conductivity, permeability, rotation, magnetic field and Coriolis force modify the existing plasma wave spectra (Gekker 1982, Jain 1986, Nicholson 1983, Artsimovich 1978, Shohet 1971, Ferraro and Plumption 1966). The starting point for modern star cosmogony is that stars are formed and reach a state similar to that of the sun owing to the gravitational condensation of rarefied clouds of gas. In this direction the gravitational instability is one of the fundamental concepts of modern astrophysical plasma and it is connected with the fragmentation of interstellar matter in regard to star formation. James (1902) first discovered gravitation instability of infinite homogeneous gaseous plasma and suggested that an infinite homogeneous self-gravitating fluid is unstable for all wave number which is less than critical Jeans wave number. A detailed contribution of the self-gravitational instability with different assumptions on the magnetic field and rotation has been given by Chandrasekhar (1961). In this connection, many researchers have discussed the

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gravitational instability of a homogenous plasma considering the effects of various parameters (Bhatia 1967, Chhajlani *et al.* 1978, Sanghvi and Chhajlani 1986, Chhajlani and Parihar 1993, Ali and Shukla 2006, Pensia *et al*. 2008, Herrneggers 1972, Pensia *et al*. 2009, Prajapati *et al*. 2010).

Along with this, magnetic fields play important role in interstellar gas dynamics. In the interstellar medium (ISM), a large amount of energy is injected by the stars, which leads to the formation of shock waves, but when these shock waves weaken, they become large amplitude hydromagnetic Alfvén waves. It is an established fact that magnetic fields can provide pressure support and inhibit the contraction and fragmentation of interstellar clouds. The magnetic field interacts directly only with the ions, electrons and charged grains in the gas. Collisions of the ions with the predominantly neutral gas in the clouds are responsible for the indirect coupling of the magnetic field to the bulk of the gas. The degree to which the magnetic pressure is important depends upon the field strength and the fractional abundance (Langer 1978).

The problem of fluid dynamics in presence of suspended particles considering the effect of suspended particles on the onset of Bernard convection, gravitational and magneto gravitational instabilities of an infinite homogeneous medium has been interested by a group of authors lead by Sharma (Sharma 1975, Sharma and Sharma 1979, Sharma 1982) and they conclude that Jean's criterion is a sufficient condition for the instability of an infinite, homogeneous magnetized self-gravitational gas particle medium in the presence of suspended particles and the finite conductivity of the medium.

In addition to this it is suggested that the Coriolis force, which usually plays no important role in physical phenomena on a laboratory scale, may often exert a dominating influence on phenomena in cosmic physics. This has been investigated by Chandrashekhar (1961) and on the basis of his study the effect of the Coriolis force on problem of thermal instability and on the stability of a viscous flow in the presence of a magnetic field have been established. Lehnert (1954, 1955) investigated the problem of magneto turbulence and pointed out that the force is important for a large range of wave numbers of disturbances in the interior of the sun.

In the above studies, authors did not consider the effects of suspended particles an Coriolis force in the fragmentation of netter in the central region of galaxy. In the present problem the authors considered the suspended particles as have been taken by a group of authors lead by Sharma (Sharma 1975, Sharma and Sharma 1979, Sharma 1982) and the parameter of Coriolis force as have been taken by Lehnert (1954, 1955). Thus the aim of the present paper was to study the effects of suspended particles and Coriolis force in the fragmentation of galaxy where, the stability of self gravitating interstellar plasma gas cloud is of considerable astrophysical significance.

In the present problem the authors found different modes of propagation of waves through media. The first mode of propagation showed the combined effects of permeability and suspended particles which was able to predict the complete information about the magnetohydrodynamic waves under the action of Coriolis force and instabilities of the hydromagnetic fluid plasma considered.

The second mode of propagation represents the combined effect of viscosity, electrical resistivity, suspended particles and Coriolis force on the self gravitational instability of a homogeneous plasma which will help to understand the fragmentation of matter.

In order to check the stability of system the authors used the Routh-Hurwitz criteria (Chhajlani and Parihar 1993, Pensia *et al.* 2008, Vyas and Chhajlani 1988). According to which the coefficients of the equation are all positive, satisfy the necessary condition of stability. For the sufficient condition the Routh-Hurwitz coefficients must be positive for any equation as

$$a_0x^n + a_1x^{n-1} + a_2x^{n-2} + a_3x^{n-3} + \ldots\ldots + a_n = 0.$$

The Routh-Hurwitz coefficients are defined as

$$\Delta_1 = \begin{vmatrix} a_0 & 0 \\ a_2 & a_1 \end{vmatrix}, \quad \Delta_2 = \begin{vmatrix} a_1 & 0 \\ a_3 & a_2 \end{vmatrix}, \quad \Delta_3 = \begin{vmatrix} a_1 & a_0 & 0 \\ a_3 & a_2 & a_1 \\ a_5 & a_4 & a_3 \end{vmatrix} \text{ etc.}$$

During discussion the authors checked that various equations (which represent different mode of propagation) whether satisfy the Routh-Hurwitz criterion or not. It was found that stability of system was valid under Jeans criterion.

AN ESTIMATE OF THE CORIOLIS FORCE

In the theory of turbulence as mentioned above, (Lehnert 1954, Lehnert 1955) the relative importance of the action on turbulent intensity by an angular velocity 'Ω' and an external magnetic fluid, 'B' is given by the ratio

$$\chi_c = \frac{\Omega(\mu\rho)^{2/2}}{KB}, \tag{1}$$

where μ is the absolute permeability, ρ is the density of the medium, and K is the wave number, which is supposed to be parallel with $\vec{B}$. It is early seen from dimensional consideration that χ_c denotes the ratio between the Coriolis force $\vec{f}_e$, and the electromagnetic force $\vec{f}_m$.

$$\vec{f}_e = \rho\vec{u} \times \vec{\Omega} = \rho\Omega_c\upsilon_c 2\vec{u}'\times\vec{\Omega}'. \tag{2}$$

And

$$\vec{f}_m = (curl\vec{h}) \times \vec{B} = \frac{B_c^{\ z}}{\mu L_c} \times curl\vec{h}'\times\vec{B}') \ , \tag{3}$$

the primed variables in equations (2) and (3) are dimensional and B_c, $\vec{U}_c$, $L_c = 2\pi/K_c$ and $\vec{i}_c = L_c/T_c = \vec{U}_c = \Omega_c, L_c$ are the characteristic values of the actual configuration and the state of motion. In equations (2) and (3) u, Ω and h are characteristic values of velocity, angular velocity and perturbed value of magnetic field and u', Ω' and h' are their dimensionless values. Authors obtained

$$\left|\frac{\vec{f}_e}{\vec{f}_m}\right| = \chi_c^{\ 2} G'. \tag{4}$$

where G' is a function of the dimensionless variables only. The Coriolis force is introduced due to the velocity of particles of gas and suspended with respect to rotating frame of reference.

MATHEMATICAL MODEL

Authors consider an infinite homogeneous self-gravitating gas particle medium in the presence of a uniform magnetic field $\vec{H}$ (0, 0, H), which is rotating with uniform angular velocity Ω, where, r is the radius vector from the origin on the axis of rotation and P is the pressure. Let $\vec{u}, \vec{v}, \rho$ and N be the gas velocity, the particle velocity, the density of the gas and the number density of particles. If assumed uniform particle size, spherical shape and small relative velocities between the two phases, then the net effect of particle on the gas is equivalent to an extra body force term per unit volume K_sN $(\vec{u} - \vec{v})$ and is added to the momentum transfer equation for gas, where the constant K_s is given by Stokes drag formula $Ks = 6\pi\rho\nu r_p$, r_p is the particle radius and ν is the kinetic viscosity of clean gas. Self gravitational attraction is added with kinetic viscosity term in equation of motion for gas. The induced magnetic field is denoted by h.

In writing the equation of motion for particle equation (9) [detail of it is given in appendix A] as taken by Vyas and Chhajlani (1988), the buoyancy force is neglected as its stabilizing effect for the case of two-free boundaries is extremely small. Interparticles reactions are also ignored by assuming the distance between particles to be two large compared with their diameters. The stability of system is investigated by writing the solution to the full equations as initial state plus a perturbation. The initial state of the system is taken to be a quiescent layer with a uniform particle distribution. The equations thus obtained are linearized by neglecting the product of perturbed quantities.

Thus, the linearized perturbation equations with suspended particles governing the motion of hydromagnetic infinite electrically conducting in compressible fluid plasma rotating with a uniform angular velocity are given, as have been taken by Lehnert (Lehnert 1954, Lehnert 1955) for Coriolis force and for suspended particles have been by a group of authors lead by Sharma (Sharma 1975, Sharma and Sharma 1979, Sharma 1982). In this paper the authors investigated the combined influence of Coriolis force and suspended particles on the fragmentation of matter in the interstitial plasma.

The magnetohydrodynamic equations of an incompressible fluid with infinite electrical conductivity are as (Lehnert 1954, Lehnert 1955)

$$\vec{\nabla} \times \vec{h} = \vec{j}, \quad Curl\ \vec{E} = -u \frac{\partial h'}{\partial t'} \tag{5}$$

$$\vec{E} + \mu \vec{u} \times (\vec{H} + \vec{h}) = 0\ . \tag{6}$$

Magnetic flux conservation equation

$$\vec{\nabla}.\vec{h} = 0. \tag{7}$$

Mass conservation equations

$$\frac{\partial N}{\partial t} + \vec{\nabla}.(N\vec{u}) = 0 \tag{8}$$

The momentum transfer equation for fluid including extra body force term per unit volume $K_s(\vec{v} - \vec{u})$, where the constant K_s is given by Stoke’s drag formula $K_s = 6\pi\rho v r_p$.

$$mN\left[\frac{\partial \vec{u}}{\partial t} + (\vec{u}.\vec{\nabla})\vec{u}\right] = KN(\vec{v} - \vec{u}) \tag{9}$$

where mN is the mass of the particle per unit volume.

Equation of motion

$$\rho\left[\frac{\partial \vec{u}}{\partial t} + (\vec{u}.\vec{\nabla})\vec{u} + 2\Omega \times \vec{u} + \vec{\Omega} \times (\vec{\Omega} \times \vec{r})\right]$$

$$= \mu i \times (\overline{G} + \vec{h}) - \vec{\nabla} p + \upsilon\rho(\nabla^2 \vec{u} - \frac{\vec{u}}{K_2} + K_s N(\vec{v} - \vec{u})\ . \tag{10}$$

The collision between suspended particles and fluid is given as

$$\left(\tau \frac{\partial}{\partial t} + 1\right)\vec{v} = \vec{u}\ . \tag{11}$$

where $\frac{m}{K_s} = \tau$ (Appendix A)

The continuity equation for fluid is as:

$$\vec{\nabla}.\vec{u} = 0\ . \tag{12}$$

MHD-field equation: An elimination of $\vec{j}$ and $\vec{E}$ is analogous to the deduction by Lehnert (1954), is given as

$$\left(\frac{\partial}{\partial t}-\eta\nabla^2\right)\overline{h}=(\vec{H}.\vec{\nabla})\vec{u}+\vec{\nabla}\times(\vec{u}\times\vec{h})\ . \tag{13}$$

$$\left(\tau\frac{\partial}{\partial\tau}+1\right)\left[\frac{\partial}{\partial\tau}-\nu\left(\nabla^2 u-\frac{1}{k_2}\vec{u}\right)\right]\vec{u}=\frac{\mu}{\rho}\left(\tau\frac{\partial}{\partial t}+1\right)(\vec{H}.\vec{\nabla})\vec{h}+\left(\tau\frac{\partial}{\partial t}+1\right)2\vec{u}\times\vec{\Omega}-$$

$$\left(\tau\frac{\partial}{\partial t}+1\right)\vec{\nabla}\phi+\left(\tau\frac{\partial}{\partial t}+1\right)\frac{\mu}{\rho}\vec{h}\times(\vec{H}\times\vec{h})+\left(\tau\frac{\partial}{\partial t}+1\right)[\vec{u}\times(\vec{\nabla}\times\vec{u})]-K_2N\frac{\tau}{\rho}\frac{\partial\overline{u}}{\partial t} \tag{14}$$

and $$\phi=\frac{p}{\rho}+\phi_c+\phi_0+\frac{\mu}{\rho}(\vec{H}.\vec{h})+\frac{\rho u^2}{2} \tag{15}$$

where ϕ_c is the centrifugal potential and ϕ_0 is the static value of ϕ.

DISPERSION RELATION

Let us consider plane waves propagated in the Z-direction, so that all perturbed quantities vary as

$$exp\ \{i(kz+\omega t)\}\approx exp\{ik(z+ct)\} \tag{16}$$

where k is wave number, ω is the growth rate of the perturbation and $c = \omega$ / k is velocity of propagation.

From equations (7) and (12)

$$\frac{\partial u_z}{\partial y}=\frac{\partial h_z}{\partial y}=0 \tag{17}$$

which shows that the waves are transverse because the gradient of velocity and magnetic field in z-direction is zero thus

$$u=(ux,\ uy,\ 0)\text{ and }h=(hx,\ hy,\ 0). \tag{18}$$

Then equation (13) becomes

$$(i\omega+\mu k^2)h_x=ikH_zu_x. \tag{19}$$

$$(i\omega+\mu k^2)h_x=ikH_zu_v. \tag{20}$$

$$h_z=u_z=0. \tag{21}$$

Equation (14) becomes as

$$(i\tau\omega+1)(i\omega+\Omega\nu)u_x=\frac{i\mu}{\rho}(i\tau\omega+1)KH_zh_x+(i\tau\omega+1)2\Omega_zu_y+\frac{K_sN\tau}{\rho}i\omega u_x \tag{22}$$

$$(i\tau\omega + 1)(i\omega + \Omega v)u_y = \frac{i\mu}{\rho}(i\tau\omega + 1)KH_z h_y + (i\tau\omega + 1)2\Omega_z u_x + \frac{K_s N\tau}{\rho} i\omega u_t \tag{23}$$

and

$$2(\Omega yux - \Omega xuy)(i\tau\omega + 1) - (i\tau\omega + 1) - \frac{\partial}{\partial z}\Phi - \frac{1}{2}\frac{\partial}{\partial z}\left[\frac{\mu}{\rho}\left(h_x^2 + h_y^2\right) - \left(u_x^2 + u_y^2\right)\right] = 0 \tag{24}$$

Equations (19) - (24) can be written

$$[X]\,[Y] = 0,$$

where [X] is the fifth order square matrix and [Y] is a single column matrix whose elements are *hx*, *hy*, *ux*, *uy*, and Φ. For a nontrivial solution of the equation (25) the determinant of the matrix [X] should vanish, leading to the general dispersion relation.

$$(\tau\sigma + 1)M_1\{M_2(\tau\sigma+1) - \frac{\sigma K_s N\tau}{\rho}\}\{M_1M_3(\tau\sigma + 1) - \frac{\sigma K_s N\tau}{\rho} - (\tau\sigma+1)\, V_A^2K^2\}+\sigma[2\Omega_m\Omega_v^2 +$$

$$2\Omega_m^2\Omega_v + 8\Omega_m\Omega^2 + 2k^2V_A^2\,\{\Omega_m+\}] + 4\Omega^2\Omega_m^2 + \Omega_m^2\Omega_v^2 + k^2V_A^2\Omega_m\Omega_v + V_A^2k^4 = 0 \tag{26}$$

where $V_A = H_z(\mu/\rho)^{\frac{1}{2}}$ is Alfvén velocity in direction of K.

$$i\omega = \sigma,\ \Omega_m = \eta k^2,\ \Omega_v = \nu\,(k^2 + \frac{1}{k_2}),\ M_1 = (\sigma + \Omega_m),\ M_2 = (\sigma + \Omega_v), \tag{27}$$

The dispersion relation (26) shows the combined influence of suspended particle viscosity, permeability, electrical conductivity, rotation and magnetic field on the magnetohydrodynamic waves under the action of Coriolis force. It is found that in this dispersion relation the terms due to the permeability and suspended particles have entered through the factor $(\rho\tau + 1)$ and $K_sN\tau/\rho$. If the effect of suspended particles is ignored, then eq. (26) reduces to Lehnert (1955). Thus with this corrections we find that the dispersion relation (26) is modified due to the combined effects of permeability and suspended particles. This dispersion relation will be able to predict the complete information about the magnetohydrodynamic waves under the action of Coriolis force and instabilities of the hydromagnetic fluid plasma considered. The above dispersion relation is very lengthy and study the effects of each parameter we now reduces the dispersion relation using normal mode analysis and we also discuss the stability of the system using Routh-Hurwittz criterion.

DISCUSSION OF DISPERSION RELATION

The dispersion relation (26) have two independent factors, each represents the mode of propagation incorporating different parameters. The first factor of dispersion relation (26) equating to zero, then

$$\sigma + \frac{1}{\tau} = 0\,. \tag{28}$$

Equation (28) represents stable mode due to suspended particles and it is clear that suspended particles of fluid oppose the fragmentation of matter in the central region of galaxy.

The second factor of the dispersion relation (26) equating to zero,

$$\alpha_0\sigma^6 + \alpha_1\sigma^5 + \alpha_2\sigma^4 + \alpha_3\sigma^3 + \alpha_4\sigma^2 + \alpha_5\sigma + \alpha_6 = 0. \quad (29)$$

where $\alpha_0 = 1$

$$\alpha_2 = \frac{2R_2}{\tau}.$$

$$\alpha_2 = \frac{2R_2}{\tau} + \frac{2R_2^{\ 1}}{\tau^2} - 4\Omega_z^{\ 2}.$$

$$\alpha_3 = \frac{2R_4}{\tau} + \frac{R_2}{\tau_2}(R_2 + R_3) + \frac{R_1^{\ 2}K^2V_A^{\ z}}{\tau^2} - \frac{8\Omega_z^{\ 2}R_5}{\tau}$$

$$\alpha_4 = \frac{2R_2R_4}{\tau_2} + \frac{R_3}{\tau}\left(\frac{R_2}{\tau}K^2V_A^{\ 2}\right) + \left(\frac{4\Omega_z^{\ 2}}{\tau} + 2\Omega_m\right).$$

$$\alpha_5 = \frac{2R_4}{\tau^2}(R_2 + R_3) + \frac{R_4K^2V_A^{\ 2}}{\tau} - \frac{2\Omega_z^{\ 2}R_5\Omega_m}{\tau^2}.$$

$$\alpha_6 = \frac{1}{\tau^2}(R_4^{\ 2} + \Omega_m^{\ 2}).$$

where $\tau_1 = (\Omega_m + \Omega_v)$ $\quad R_1 = \left(1 + \tau r_1 - \frac{K_sN\tau}{\rho}\right)$ $\quad R_2 = \left(r_1 + \tau\Omega_m\Omega_v - \frac{\Omega_mK_sN\tau}{\rho}\right\}$

$R_3 = (\tau K^2V_A^{\ 2} + R^2)$ $\quad R_4 = (K^2V_A^{\ 2} + \Omega_m\Omega_v)$ $\quad R_5 = (1 + \tau\Omega_m)$

This dispersion relation (29) shows the combined influence of viscosity, electrical resistivity, suspended particles and Coriolis force on the self-gravitational instability of a homogeneous plasma in the central region of galaxy. This dispersion relation will be able to predict the complete information about the fragmentation of matter (Fluid plasmas) considered.

In order to discuss the dynamical stability of the system represented by (29), authors applied the Routh-Hurwitz criterion [as introduction and taken by Vyas and Chhajlani (1988)]. According to this criterion, the necessary condition that all the coefficients of the polynomial equation (29) should be positive. In order to satisfy the sufficient condition, authors calculate the minors of the Hurwitz-Matrix formed by these coefficients, which are

$$\Delta_1 = \frac{2_R^{\ 2}}{\tau}.$$

$$\Delta_2 = \frac{3R_2R_3}{\tau^2} + \frac{8\Omega_z^2}{\tau}(R_5 - R_1) + \left(2R_2^2 - \frac{R_2}{\tau} - K^2V_A^2\right) - \frac{2R_4}{\tau}.$$

$$\Delta_3 = \frac{64R_5\Omega_z^2}{\tau^2}(R_1 - R_5) + \left(\frac{2R_2^4}{\tau^4} - \frac{8R_1^2\Omega_z^2}{\tau^2}\right)\left(\frac{R^2}{\tau} + \frac{R_3}{\tau} + K^2V_A^2\right) + \frac{R^3R^2}{\tau^3}$$

$$\left(6R_4 + \frac{3R_2R_3}{\tau} - 2R_2\left(\frac{R^2}{\tau} + K^2V_A^2\right)\right) + \frac{2R_4}{\tau^2}\left(\frac{R_2^1}{\tau} + R_1K^2V_A^2 - \frac{2R_1^3}{\tau^2} - 2R_4\right) - \frac{R_1^2}{\tau^2}$$

$$\left(\frac{R_2^2}{\tau^2} + K^2V_A^2\left(1 + \frac{2R_2}{\tau}\right)\right) + \frac{16R2\Omega_z^2}{\tau}\left(\frac{R_5}{\tau}\left(\frac{R_2}{\tau} + K^2V_A^2 + \frac{R^2}{\tau} - \frac{R_3}{\tau} - \frac{R_1^2}{\tau^2}\right) - \frac{R_4}{\tau}\right) +$$

$$\frac{4R_2\Omega_m\Omega_z^2}{\tau}\left(\frac{2R_1}{\tau} - \frac{R_5}{\tau}\right) + \frac{4R_2}{\tau}\left(\frac{8R_5\Omega_z^2}{\tau} - \frac{R_2}{\tau}\left(\frac{R_2}{\tau} + K^2V_A^2\right)\right)$$

$$\Delta 4 = \frac{1}{\tau^2}\left(2R_4^2 - \Omega_m^2\right)\Delta_3$$

It is clear that all the Δ's may be positive or negative depend upon the value of τ if $\tau >> 1$ then some Δ's are negative which means that the matter is dominated by fragmentation or the stabilizing and if $\tau << 1$ then all the Δ's are positive, which means that the system tends towards stability.

Now the stability of the medium corresponding to infinite conductivity ($\eta = 0$) plasma is analysed. For this case equation (23) takes a form with all coefficients positive which is a necessary condition for the stability of the system. To obtain the sufficient condition, the principal minors of the Hurwitz-matrix must be positive and get

$$\Delta_1 = \frac{2R_2'}{\tau}.$$

$$\Delta_2 = \frac{3R_2'R_3'}{\tau^2} - \frac{8R_2'\Omega_z^2}{\tau} + \frac{R_2'}{\tau}\left(\frac{2R_1'^2}{\tau^2} - \frac{R_1'^2}{\tau^2}\right) - \frac{2K^2V_A^2}{\tau}.$$

$$\Delta_3 = \frac{64\Omega_z^2}{\tau}(R_1' - 1) + \frac{2R_3'R_1'^2}{\tau^3}\left(\frac{2R_1'^2}{\tau^2} - 8\Omega_z^2\right) + \frac{R_1'R_3'}{\tau^3}\left(6K^2V_A^2 + \frac{R_1'R_3'}{\tau}\right) + \frac{2K^2V_A^2}{\tau^2}$$

$$\left(\frac{R_1'^2}{\tau} + \frac{K^2V_A^2R_2'}{\tau} - \frac{2R_1'^3}{\tau^2} - \frac{2K^2V_A^2}{\tau^2}\right) - \frac{R_1'^2}{\tau^2}\left(\frac{\Omega_v^2}{\tau^2} + \frac{R_3'}{\tau} + \frac{\Omega_v}{\tau}\right) + \frac{16R_1'\Omega_z^2}{\tau^2}$$

$$\left(\frac{R_1'}{\tau^2}\left(1 - \frac{R_1'}{\tau}\right) - \frac{K^2V_A^2}{\tau}\right) + \frac{4K^2V_A^2}{\tau}\left(\frac{8\Omega_z^2}{\tau} - \frac{R_1'R_3'}{\tau}\right).$$

$$\Delta_4 = \frac{2}{\tau^2}(K^2V_A^2)^2\Delta_3.$$

$$R_1' = \left(1 + \tau\Omega_v - \frac{K_3M\tau}{\rho}\right), \qquad R_2' = \Omega_v \qquad R_3' = (\tau K^2V_A^2 + \Omega_v), \qquad R_4' = K^2V_A^2.$$

For non-rotating and infinitely conducting media, the Δ's are given as

$$\Delta_1 = \frac{2R_2}{\tau}.$$

$$\Delta_2 = \frac{3R_2'R_3'}{\tau^2} + \frac{R_2}{\tau}\left(\frac{2R_1'^2}{\tau^2} - \frac{R_1'^2}{\tau^2}\right) - \frac{2K^2V_A^2}{\tau}.$$

$$\Delta_3 = \frac{R_1'R_3'}{\tau^2}\left(\frac{R_1'^3 2}{\tau} + \frac{2K^2V_A^2}{\tau} + \frac{R_1'R_3'}{\tau}\right) + \frac{2K^2V_A^2}{\tau^2}\left(\frac{R_1'^2}{\tau} + \frac{K^2V_A^2R_2'}{\tau} - \frac{2R_1'^3}{\tau} - \frac{K^2V_A^2}{\tau^2}\right)$$
$$- \frac{R_1^2}{\tau^2}\left(\frac{\Omega_v^2}{\tau^2} + \frac{R_3'}{\tau} + \frac{\Omega_v}{\tau}\right).$$

$$\Delta_4 = \frac{2}{\tau^2}(K^2V_A^2)^2\Delta_3.$$

So, it is seen that all the Δ's are positive. It means that non-rotating and infinitely conducting media are stable. In the absence of suspended particles the dispersion relation (26) can be reduced as earlier obtained by Lehnert (Lehnert 1954, Lehnert 1955) and given as

$$[(\sigma + \Omega_m)(\sigma + \Omega_v) + K^2V_{AZ}^2]^2 = -4\Omega^2(\sigma + \Omega_m)^2 \tag{30}$$

$$V_{AZ} = V_A\cos\phi, \quad \Omega_z = \Omega\cos\phi. \tag{31}$$

The solution of the dispersion relation (30) can be written as

$$\pm\sigma = KV_{AZ}\,[\pm\xi_1 + i(\xi_2 + \xi_3) \pm \{1 + [\xi_2 \pm i(\xi_3 - \xi_2)]^2\}^{1/2}], \tag{32}$$

where $\xi_1 = \dfrac{\Omega_{AZ}}{KV_{AZ}}$; $\xi_2 = \dfrac{\Omega_v}{2V_{AZ}}$; $\xi_3 = \dfrac{\Omega_m}{2V_{AZ}}$;

It is noted that the right hand side of equation (32) is related with four different types of waves whereas the left hand side is related with two possible wave fronts which is propagating in the opposite direction. For small values of ξ_1, ξ_2 and ξ_3 it is

$$|\xi_1| \approx \left|\frac{\Omega_z}{\sigma}\right| = \frac{\tau_2}{\tau_3}|\cos\phi| \tag{33}$$

From equation (33) it is clear that the Coriolis force is more dominated for a wave with a period, τ_2 as compared to the period of revolution, τ_3 of the medium.

CONCLUSION

In this paper, authors investigated the problem of fragmentation of matter in the central region of galaxy in the presence of suspended particles under the effect of Coriolis force. The general dispersion relation is obtained, which is modified due to the presence of these parameters. The general dispersion relation is reduced in the different cases of interest. It was found that the presence of suspended particles modifies the fundamental criterion of fragmentation of matter and it is stable damped mode. The stability of the system is discussed by Routh-Hurwitz criterion. Authors found that all the coefficients of minors of the Hurwitz matrix may be positive or negative depends upon the value of τ and if $\tau >> 1$ then all the coefficient of Hurwitz matrix is negative which means that the matter is dominated by fragmentation then stability and if $\tau << 1$ the system tends to towards stability.

It is also found that resistivity of the medium has destabilizing influence on the system where viscosity has a stabilizing influence on the system. In the absence of suspended particles with some assumptions such as viscosity, resistivity and rotational parameters are small, then the Coriolis force is more dominated for a wave with the period as compared to the period of revolutions of the system.

Appendix A

The equation (9) represents the momentum transfer of gaseous particles under the influence of stokes drag effect.

$$\frac{m}{Ks}\left[\frac{\partial \bar{u}}{\partial t}\right]+\frac{m}{Ks}\left[(\vec{u}.\vec{v})\vec{u}\right]=(\vec{v}-\vec{u}) \tag{A}$$

Let $\tau = \dfrac{m}{Ks}$, and $[(\vec{u}.\vec{\nabla})\vec{u}]=0$ then equation (A) becomes

$$\tau\left[\frac{\partial \bar{u}}{\partial t}\right]+(\vec{v}-\vec{u})\,. \tag{B}$$

$$\tau\left[\frac{\partial \bar{u}}{\partial t}\right]+\vec{u}=\vec{v}\,. \tag{C}$$

$$\left(\tau\frac{\partial}{\partial t}+1\right)\vec{u}=\vec{v}\,. \tag{D}$$

REFRENCES

Ali, S. and P. K. Shukla. 2006. Jeans instability in a plasma with positive–negative charged and neutral dust components. *Phys. Scr.* **73**: 359.

Artsimovich, L. A. 1978. *A Physicist's ABC on Plasma.* Mir Publication, Moscow.

Bhatia, P. K. 1967. Gravitational Instability of a Rotating Anisotropic Plasma. *Physics. of Fluids*. **10**: 1652-1653.

Chandrashekhar, S. 1961. *Hydrodynamics and Hydromagnetic Stability*. Clarendon Press, Oxford.

Chhajlani, R. K., P. Vashistha, and S. C. Bhand. 1978. Effect of Conductivity on Magneto-Gravitational Instability and Suspended Particles. *Z. Naturforsch* **339:**1469.

Chhajlani, R.K. and A.K. Parihar. 1993. Stability of Self-Gravitating Magnetized Hall Plasma with Electrical and Thermal Conductivity through Porous Medium. *Contrib. Plasma Phy.* **33(3):** 227-234.

Ferraro, V. C. A. and C. Plumption. 1966. *An introduction to Magneto Fluid Mechanics.* Oxford University Press.

Gekker I. R. 1982. *Interaction of Strong Electromagnetic Field with Plasmas*. Clarendon Press, Oxford.

Herrengger, F. J. 1972. Effects of Collisions and Gyroviscosity on Gravitational Instability in a two-Component Plasma. *J. Plasma Physics* **8**:393-400.

Jain, H. C. 1986**.** *Plasma--The Forth State of Matter*. Sterling Pub. (Pri) Ltd., New Delhi.

Jeans, J. H. 1902. The Stability of Spherical Nebula. *Phil. Trans. Ray. Soc. London* **199**:1-53.

Langer, W. D. 1978. The stability of interstellar clouds containing magnetic fields. *Astrophysical Space Journal.* **225**:95-106.

Lehnert, B. 1954. Magnetohydrodynamic Waves under the Action of the Coriolis Force. *Astrophys. J*. **119**: 647-654.

Lehnert, B. 1955. Magnetohydrodynamic Waves under the Action of the Coriolis Force II. *Astrophys. J.* **121**:481.

Nicholson, D.R. 1983. *Introduction to Plasma Theory*. John Wiley and Sons, New York.

Pensia, R. K. and V. Ghorela and R.K. Chhajlani. 2008. Thermal Instability of a Self Gravitating, Rotating Gaseous Plasma with Generalized Ohm's Law. *Ultra Scientist* **20(3)**:541-544.

Pensia, R. K. and V. Ghorela and R.K. Chhajlani. 2009. Magneto thermal instability of Self-gravitational viscous Hall plasma in the presence of suspended particle. *Acta Ciencia Indica* **35(2)**: 141-148.

Prajapati, R. P., R. K. Pensia, S. Kaothar and R. K.Chhajlani.2010.Self-Gravitational Instability of Rotating Viscous Hall Plasma With Arbitrary Radiative Heat-Loss Functions and Electron Inertia. *Astrophys. Space Sci.* **327**:139-154.

Sanghavi, R.K. and R.K. Chhajlani. 1986. Magneto-gravitational instability of a rotating and finitely-conducting fluid. *Astrophys. Space Sci*. **126**:143-153.

Sharma, K.C. 1982. Gravitational Instability of Hall Plasma in the Presence of Suspended Particles. *Astrophys. Space Sci*.**85**:263.

Sharma, R.C. 1975. Suspended Particles and the Gravitational Instability. *Zeit Apple. Math. Mech.* **55:** 615-616.

Sharma, R.C. and K.C. Sharma. 1979. Suspended Particles and the Gravitational Instability of a Rotating Plasma. *Astrophys. Space Sci.***71**:325.

Shohet, J. L. 1982. *The Plasma State.* Academic Press, New York.

Vyas, M. K. and Chhajlani R. K. 1988. Gravitational instability of a thermal-conducting plasma flowinf through a porous medium in the presence of suspended particles. *Astrophys. Space Sci.* **149**: 323-342.

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