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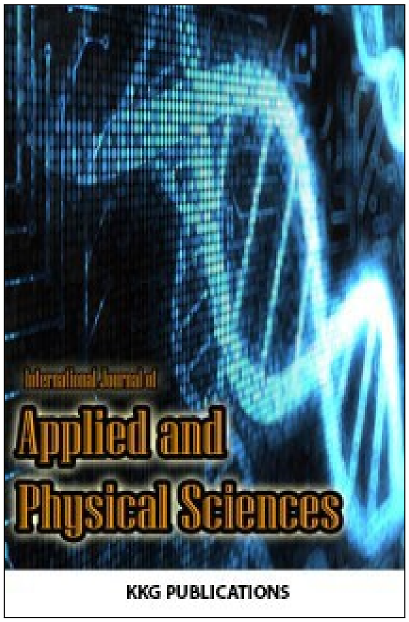

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Propagation of EMIC Waves using Kappa Distribution in the Jupiter's Magnetosphere

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PROPAGATION OF EMIC WAVES USING KAPPA DISTRIBUTION IN THE JUPITER'S MAGNETOSPHERE

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Abstract. The propagation of Electromagnetic Ion-Cyclotron (EMIC) Waves is observed in Jupiter's Magnetosphere with varying anisotropy temperature. Voyager∼2 by NASA showed Jupiter's plasma Magnetosphere contained humungous high energy particles in its tail. Thus, by using the Kinetic Theory approach for the systems of Jovian type, the growth rate for EMIC waves is iterated, and with the help of the method of characteristic solution, the dispersion relation is computed. Due to the constraint mentioned above, we apply Kappa distribution rather than Maxwellian distribution. These computations are solely focused on the parallel propagation and the oblique propagation of EMIC waves considering variation in temperature anisotropy, ions energy density, and propagation angle concerning the direction of a magnetic field. For Jupiter's magnetosphere, it is found that the above parameters support the growth rate of EMIC waves. It is also observed from the plotted graphs that EMIC waves for oblique propagation have significantly grown more than that for parallel propagation. And more the energy of ions, the more the growth is observed. Results obtained after computations are appropriate for the applications in the environment about space plasma and magnetosphere for the planetary comparative study of the solar system.

INTRODUCTION

Using Kinetic Theory approach for the systems of Jovian type, the growth rate for parallel and oblique propagation of EMIC waves is iterated and with the help of method of characteristic solution, the dispersion relation is computed. Due to above mentioned constraint, we apply Kappa distribution rather than Maxwellian distribution.

Literature Survey

In July 1979, the Voyager 2's experience of Jupiter gave the chance to watch yet another planetary magnetosphere and look at the plasma physical procedures occurring there, to those happening in magnetosphere of Earth, Uranus and Saturn [1]. The existence of magnetic field at Jupiter was uncovered with the Voyager's entry. This offered an intriguing detached research center for the investigation of magnetospheric interactions. Perceptions demonstrated plasmaic electromagnetic and electrostatic turbulence at Jupiter. Additionally, Voyager 2 traced the whistler mode emanations (melody and murmur) in the Jupiter's inner magnetosphere. Numerous specialists have considered parallel proliferating low recurrence plasma waves in the region of magnetosphere. Utilizing a progression of 1-D recreations, Zhang considered the development of whistler wave at different angles of propagation, from an anisotropic electrostatic emission of the electron light and electromagnetic wave modes [2]. Devine summed up whistler mode instability for oblique propagation in one and two dimensional reenactments [3].

The study pertinent to the investigation of particle conics specially ion within the sight of Electro Magnetic Ion Cyclotron (EMIC) wave was completed by Ahirwar in the auroral increasing speed locale of the magnetosphere of Earth [4]. His work was based on the aspect of particle approach and the impact of perpendicular and parallel resonant energies with the EMIC waves using the loss cone distribution function in homogeneous plasma for low had been talked about. In the vast majority of the work done, it was accepted that resonant particles are participating in the exchange of energy with waves, and non-resonant particles are participating in the oscillatory motion of the waves. It is finally concluded that the general distribution function applied to the electric field in parallel direction helps in controlling the growth rate of EMIC waves, and the loss-cone distribution function helps in enhancing the growth rate and heating of the ions in perpendicular direction. As ion cyclotron waves have the ability to heat and accelerate ions, their investigations are considered to be of higher priority. Also in the space studies, the electromagnetic fluctuations are found to be an interesting topic [5-7]. Research work by Cheng [8], explains about high energetic ion and electron phase space densities,

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which proves that Jovian magnetosphere is an active planetary magnetosphere that exhibits sub-storm activities, followed by Mercury and Earth. In Jupiter's magnetosphere, Suprathermal tails have been predicted and for satellite data observations kappa distribution is found suitable [9, 10, 12, 13]. Roused by above examination, we explore the low recurrence electromagnetic ion cyclotron (EMIC) waves in an inhomogeneous, impact less plasma subjected to encompassing attraction in the magnetosphere of Jupiter. By utilizing the method of characteristic solution, the dispersion relation is computed for the EMIC waves propagating parallely and obliquely to the direction of magnetic field. Since Jovian magnetospheric plasma contains more particles in high vitality tail, they are demonstrated by Kappa distribution rather than Maxwellian distribution.

PROPOSED METHODOLOGY

A homogeneous collisionless anisotropic plasma with external magnetic field $B_0 = B_0\hat{e}_z$ and an electric field $E_0 = E_0 sin(vt)\hat{e}_z$ are assumed to obtain the dispersion relation. Following the technique of Pandey [11], the growth rate and real frequency expressions for the propagation of EMIC waves parallel and oblique to the direction of magnetic field are as follows:

$$\frac{\gamma}{\omega_c} = \frac{\dfrac{\sqrt{\pi}}{\tilde{k}}\left(\dfrac{(k-1)!\,k^{k-1/2}}{(k-3/2)!}\right)(A_T - K_4)K_3^3\left\{-\left(\dfrac{k^3}{\tilde{k}}\right)\right\}^{-2k}}{1+\dfrac{k}{k-3/2}\left[\dfrac{\tilde{k}^2}{2K_3^2}+\dfrac{\tilde{k}^2}{K_3}(A_T-K_4)\right]-\dfrac{X_{1e}}{X_{1i}}K_3^2}$$

$$X_3 = \frac{\omega_r}{\omega_{ci}} = \frac{\tilde{k}^2}{\beta}\left[\frac{X_{1i}}{X_{1i}-X_{1e}} + \frac{A_T\beta X_{1i}}{2(X_{1i}-X_{1e})}\right]$$

$$\frac{\gamma}{\omega_c} = \frac{\dfrac{\sqrt{\pi}}{\tilde{k}\cos\theta}\left(\dfrac{(k-1)!\,k^{k-1/2}}{(k-3/2)!}\right)(A_T - K_4)K_3^3\left\{-\left(\dfrac{k^3}{\tilde{k}\cos\theta}\right)\right\}^{-2k}}{1+X_4+\dfrac{k\cos^2\theta}{k-3/2}\left[\dfrac{(1+X_4)\tilde{k}^2}{2K_3^2}+\dfrac{\tilde{k}^2}{K_3}(A_T-K_4)\right]-\dfrac{X_{1e}}{X_{1i}}K_3^2}$$

$$X_3 = \frac{\omega_r}{\omega_{ci}} = \frac{\tilde{k}^2\cos^2\theta}{\beta}\left[\frac{X_{1i}(1+X_4)}{X_{1i}-X_{1e}(1+X_4)} + \frac{A_T\beta X_{1i}}{2(1+X_4)(X_{1i}-X_{1e}(1+X_4))}\right]$$

Where

$$K_3 = 1 - X_3 + X_4,\ K_4 = \frac{X_3}{1 - X_3 + X_4},$$

$$X_{1i} = \theta_{\perp i}^2 - \frac{\upsilon\Gamma_{Xi}}{\omega_{ci}^2 - \upsilon^2}\frac{\theta_{\perp i}}{2}\sqrt{\pi},\quad X_{1e} = \theta_{\perp e}^2 - \frac{\upsilon\Gamma_{Xe}}{\omega_{ce}^2 - \upsilon^2}\frac{\theta_{\perp e}}{2}\sqrt{\pi}$$

PLASMA VALUES

The growth rate for EMIC waves in the magnetosphere of Jupiter is computed using Lorentzian-Kappa with the following plasma values. Magnetic field $B_o = 51 \times 10^{-9}T$, Electric field $E_o = 0.1 \times 10^{-3}V/m$ and density of electron is given by $n_o = 3 \times 10^5 m^3$. Temperature anisotropy (A_T) is varying from 1.4 to 1.6. The thermal energy of electrons $(K_b T_{lle})$ is taken to be 0.3 eV and that of energetic ions $(K_b T_{lli})$ be 1000eV.

RESULTS

In this graph, the growth rate $(\gamma/\omega c)$ varies with $\tilde{k}$ for different values of the temperature anisotropy ratio (T/T) varying from 1.4 to 1.6. For the value of $T \perp /T \parallel$ = 1.4, the growth rate = 0.2919; for $T \perp /T \parallel$ = 1.5, the growth rate = 0.3233; for $T \perp /T \parallel$ = 1.6, the growth rate = 0.4073 and the growth rate is maximum for $\tilde{k}$ = 0.12. This graph clearly indicates that there is increase in the growth rate as the temperature anisotropy is increased which in turn gives rise to the free energy which is responsible for the propagation of the EMIC waves parallel to the direction of the magnetic field in the Jupiter's Magnetosphere (fig. 1).

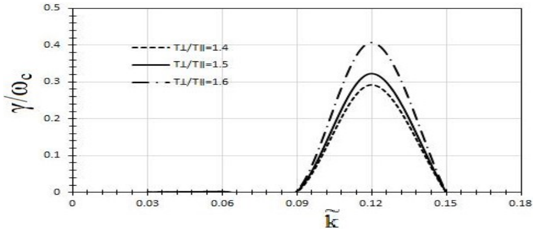

Fig. 1 . Varying Growth Rate $(\gamma/\omega c)$ with $\tilde{k}$ for different values of $T \perp /T \parallel$ at $K_b T \parallel i$= 1keV with given plasma values for propagation of EMIC waves parallel to the direction of the magnetic field

In this graph, the growth rate $(\gamma/\omega c)$ varies with $\tilde{k}$ for different values of thermal energy of ions $(K_b T \parallel)$ varying from 1keV to 3keV. For the value of $K_b T \parallel i$= 1keV, the growth rate = 0.0016; for $K_b T \parallel i$= 2keV, the growth rate = 0.00775; for $K_b T \parallel i$= 3keV, the growth rate = 0.0144 and the growth rate is maximum for $\tilde{k}$ = 0.06, 0.12 and 0.15 respectively. This graph indicates that there is increase in the growth rate of parallely propagating EMIC waves as the energy of the ions is increased (fig. 2).

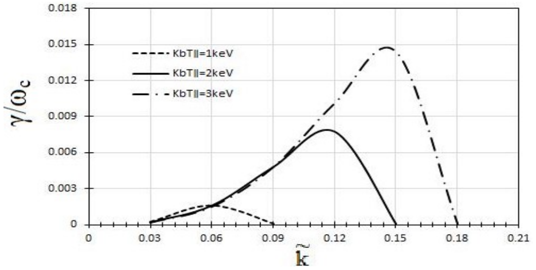

Fig. 2 . Varying Growth Rate $(\gamma/\omega c)$ with $\tilde{k}$ for different values of $K_b T \parallel i$ at $T \perp /T \parallel$ = 1.25 with given plasma values for propagation of EMIC waves parallel to the direction of the magnetic field

In this graph, the growth rate (γ/ωc) varies with $\tilde{k}$ for different values of the temperature anisotropy ratio ($T \perp /T \parallel$) varying from 1.4 to 1.6 for the oblique propagation of the EMIC waves to the direction of the magnetic field. For the value of T/T = 1.4, the growth rate = 0.3176; for $T \perp /T \parallel$ = 1.5, the growth rate = 0.4067; for $T \perp /T \parallel$ = 1.6, the growth rate = 0.6986 and the growth rate is maximum for $\tilde{k}$ = 0.12. This graph clearly indicates that the condition of the resonance changes as the growth rate of the obliquely propagating EMIC waves increases with increase in the temperature anisotropy (fig. 3).

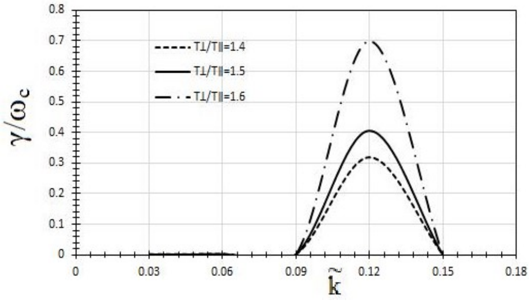

Fig. 3 . Varying Growth Rate (γ/ωc) with $\tilde{k}$ for different values of $T \perp /T \parallel$ at $K_bT \parallel i$ = 1keV with given plasma values for propagation of EMIC waves oblique to the direction of the magnetic field

In this graph, the growth rate (γ/ωc) varies with $\tilde{k}$ for different values of thermal energy of ions ($K_bT \parallel i$) varying from 1keV to 3keV for the oblique propagation of the EMIC waves to the direction of the magnetic field. For the value of $K_bT \parallel i$= 1keV, the growth rate = 0.00161; for $K_bT \parallel i$= 2keV, the growth rate = 0.00778; for $K_bT \parallel i$= 3keV, the growth rate = 0.015 and the growth rate is maximum for $\tilde{k}$ = 0.06, 0.12 and 0.15 respectively. This graph shows significant changes in the bandwidth as there is increase in the growth rate of obliquely propagating EMIC waves when the energy of the ions is increased (fig. 4).

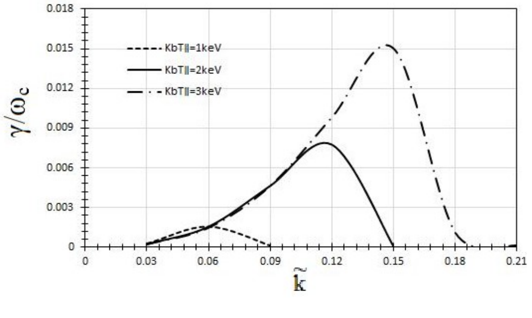

Fig. 4 . Varying Growth Rate (γ/ωc) with $\tilde{k}$ for different values of $K_bT \parallel i$ at = $T \perp /T \parallel$ 1.25 with given plasma values for propagation of EMIC waves oblique to the direction of the magnetic field

In this graph, the growth rate ($\gamma/\omega c$) varies with for different values of propagation angle (θ) varying from 10○ to 20° for the oblique propagation of the EMIC waves to the direction of the magnetic field. For the value of θ = 10°, the growth rate = 0.0677; for θ = 15°, the growth rate = 0.0888; for θ = 20°, the growth rate = 0.144; and the growth rate is maximum for $\tilde{k}$ = 0.2. This graph shows increasing values of the growth rate with the increase in the oblique propagation angle (θ) of the highly energetic ions. For propagation angle greater than 20°, an instability with non-resonance takes place by replacing the electromagnetic energy with electrostatic energy in the Jupiter's magnetosphere (fig. 5).

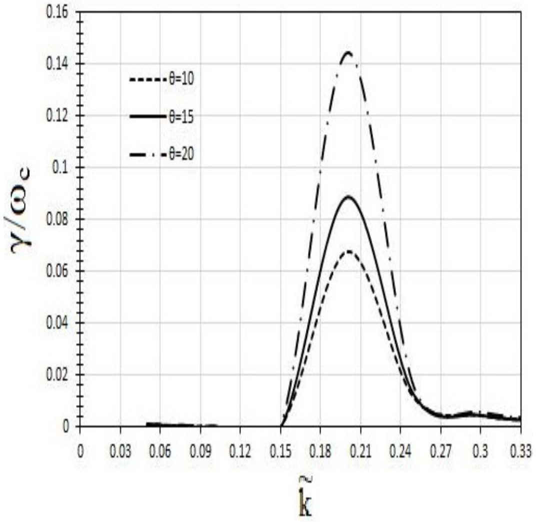

Fig. 5 . Varying Growth Rate (γ/ωc) with $\tilde{k}$ for different values of propagation angle θ at = $T \perp /T \parallel$ 1keV with given plasma values for propagation of EMIC waves oblique to the direction of the magnetic field

CONCLUSION

These computations are solely focused on parallel propagation as well as on the oblique propagation of EMIC waves considering variation in temperature anisotropy, ions energy density and propagation angle with respect to the direction of magnetic field. For Jupiter's magnetosphere, it is found that the above parameters support the growth rate of EMIC waves. It is also observed from the plotted graphs that EMIC waves for oblique propagation have significantly grown more than that for parallel propagation. And more the energy of ions, more the growth is observed. Results obtained after computations are appropriate for the applications in the environment pertaining to space plasma and magnetosphere for the planetary comparative study of the solar system.

REFERENCES

[1] D. A. Gurnett, W. S. Kurth, F. L. Scarf and R. L. Poynter, "First plasma wave observations of Uranus," *Science*, vol. 233, no. 4759, pp. 106-109, 1986.

[2] Y. L. Zhang, H. Matsumoto and Y. Omura, "Linear and nonlinear interactions of an electron beam with oblique whistler and electrostatic waves in the magnetosphere," *Journal of Geophysical Research: Space Physics*, vol. 98, no. A12, pp. 21353-21363, 1993.

[3] P. E. Devine, S. C. Chapman and J. W. Eastwood, "Oneand twodimensional simulations of whistler mode waves in an anisotropic plasma," *Journal of Geophysical Research: Space Physics*, vol. 100, no. A9, pp. 17189-17203, 1995.

[4] G. Ahirwar, P. Varma and M. S. Tiwari, "Electromagnetic ion-cyclotron instability in the presence of a parallel electric field with general loss-cone distribution function-particle aspect analysis," *Annales Geophysicae*, vol. 24, no. 7, pp. 1919-1930, 2006.

[5] J. Huang, J. Han, H. Li, M. Cai, X. Li, Z. Zhang, Z. Chen, L. Wang, X. Yang and C. Feng, "Mechanism and operation parameters of a plasma-driven micro-particle accelerator," *Chinese Science Bulletin*, vol. 54, no. 4, pp. 616-622, 2009.

[6] L. Li, J. Cao, G. Zhou, J. Yang, C. Yan, T. Zhang, H. Reme, I. Dandouras, C. M. Carr, "Shrinkage of magnetosphere observed by TC-1 satellite during the high-speed solar wind stream," *Science in China Series E: Technological Sciences*, vol. 51, no. 10, pp. 1695-1703, 2008.

[7] C. Shen, Z. Liu, C. P. Escoubet, C. M. Carr, H. Reme, A. Fazakerley, H. Laakso, Q. Shi, I. Dandouras, T. Zhang, S. Wang, X. Yang, M. Dunlop, J. Cao, "Surveys on magnetospheric plasmas based on the Double Star Project (DSP) exploration," *Science in China Series E: Technological Sciences*, vol. 51, no. 10, pp. 1639-1647, 2008.

[8] B. H. Mauk, S. M. Krimigis, E. P. Keath, A. F. Cheng, T. P. Armstrong, L. J. Lanzerotti, G. Gloeckler, D. C. Hamilton, "The hot plasma and radiation environment of the Uranian magnetosphere," *Journal of Geophysical Research: Space Physics*, vol. 92, no. A13, pp. 15283-15308, 1987.

[9] S. M. Krimigis, T. P. Armstrong, W. I. Axford, C. O. Bostrom, C. Y. Fan, G. Gloeckler and L. J. Lanzerotti, "The low energy charged particle (LECP) experiment on the Voyager spacecraft," *Space Science Reviews*, vol. 21, no. 3, pp. 329-354, 1986.

[10] V. Pierrard and M. Lazar, "Kappa distributions: Theory and applications in space plasmas," *Solar Physics*, vol. 267, no. 1, pp. 153-174, 2010.

[11] R. S. Pandey, R. P. Pandey, A. K. Srivastav and K. Dubey, "Analytical study of whistler mode instability with parallel ac field by Lorentzian Kappa," *Indian Journal of Radio and Space Physics*, vol. 34, no. 2, pp. 98-105, 2005.

[12] K. Min, J. Lee, K. Keika, and W. Li, "Global distribution of EMIC waves derived from THEMIS observations," *Journal of Geophysical Research: Space Physics,* vol. 117, no. A5 pp. 1-13, 2012.

[13] N. P. Meredith, R. B. Horne, T. Kersten, B. J. Fraser, and R. S. Grew, "Global morphology and spectral properties of EMIC waves derived from CRRES observations," *Journal of Geophysical Research: Space Physics,* vol. 119, no. 7, pp. 5328-5342, 2014.

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