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Study on Electromagnetic Electron Cyclotron (EMEC) Waves around Plasma-Pause Region

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Abstract

Electromagnetic electron cyclotron (EMEC) waves have been studied for general loss-cone distribution function with temperature anisotropy around plasma-pause region. Electromagnetic electron cyclotron (EMEC) waves have been studied by kinetic approach. The effect of general loss-cone distribution function with temperature anisotropy on EMEC instability is evaluated the dispersion relation, growth rate. The main objective of the present investigation is to examine the effect of general loss-cone distribution index J with temperature anisotropy in view of the plasma-pause region. It is observed that the effect of increasing the distribution index is to increase the growth rate. The results are interpreted for the space plasma parameters appropriate to the plasma-pause region in magneto-plasma.

Keywords: Electromagnetic electron-cyclotron waves, plasma-pause region, solar plasma, general loss-cone distribution function, temperature anisotropy.

Introduction

Electron cyclotron waves are electromagnetic waves it is a right-hand circularly polarized wave with a frequency in the range of the electron cyclotron frequency. Anisotropic electron distributions occur naturally during the generation, confinement and heating of plasma in confinement. The wave interacts strongly with those particles that have a Doppler-shifted wave frequency in the neighborhood of their cyclotron frequency[1]. This combination of narrow, steerable beams and localized power deposition is unique for electron cyclotron resonance heating (ECRH) and current drive (ECCD). ECRH heat the plasmas heated by other additional heating methods. It is well known that the ECH waves can be excited by an electrostatic instability induced when an electron velocity distribution function $F(v_\|, v_\perp)$ (where $v_\|$ and $v_\perp$ are velocity components parallel and perpendicular to the ambient magnetic field, respectively) has a region of positive gradient, i.e., $\partial F/\partial v_\perp > 0$. Thus, a loss cone or ring velocity distribution is likely to drive ECH waves unstable, and the presence of the cold background electrons strongly affects the growth rates[2-7] which may explain the enhancement of such waves near the plasma pause. The role of low density up flowing field-aligned electron beams (FEBs) on the growth rate of the electron cyclotron waves at the frequencies $\omega_r < \Omega_e$ propagating downward in the direction of the Earth's magnetic field, has been analyzed in the auroral region at $\omega_e/\Omega_e < 1$ where ω_e is the plasma frequency and Ω_e is the gyro frequency. Several workers have reported the existence of up flowing, we down flowing, and counter streaming field-aligned electron beams (FEBs) in the auroral region. FEBs are responsible for the linkage between magnetospheric and ionospheric plasmas.

The wave polarization was dominantly left-handed around the equatorial region and inner side of source region, but appeared right-handed close to the outer edge of the plasma pause and at higher latitudes. The Poynting flux and minimum variance analysis indicate that the wave energy was mainly transported towards high latitudes though oblique propagation was seen around the equatorial region. These observations suggest the waves originated around the equatorial region in the high density outer plasmasphere-plasmapause which overlaps the ring current; ideal conditions for wave generation by the cyclotron instability.

The main aim of this study is to investigate the generation of EMEC waves in view of the plasma-pause region parameter use and see the effect of general loss-cone distribution function with temperature anisotropy in magnetospheric plasma. The detailed description and formulae for the dispersion relation and growth rate is determined in the next section.

Methodology

Distribution function: We consider a general distribution function for $f_\perp(v_\perp)$ and $f_\|(v_\|)$ as[8]

$$N(y,V) = N_0 f_\perp(V_\perp) f_\Pi(V_\Pi) \quad (1)$$

We consider a general loss-cone distribution function for $f_\perp(V_\perp)$ as

$$f_\perp(V_\perp) = [\frac{V_\perp^{2J}}{\pi V_{T\perp}^{2(J+1)} J!}] \exp(-\frac{V_\perp^2}{V_{T\perp}^2}) \quad (2)$$

and $f_\Pi(V_\Pi)$ which is defined by the drifting Maxwellian

$$f_{\Pi}(V_{\Pi}) = \left(\frac{1}{\sqrt{\pi}\,V_{T\Pi c}}\right)\exp\{-(V_{\Pi})^2 / V_{T\Pi c}{}^2\} \quad (3)$$

Where J is the distribution index and measures the loss-cone feature [8]. In the case of J=0 this represents a bi-Maxwellian distribution $V_{T\Pi c}{}^2 = \frac{2T_{\Pi c}}{m}$ and $V_{T\perp}{}^2 = (J+1)^{-1}\frac{2T_{\perp}}{m}$.

Dispersion Relations: The dispersion relation for the right hand circular polarized electromagnetic (whistler mode) wave preparative exactly parallel to the external B_0 is given by[9].

$$\frac{c^2k^2}{\omega^2} = \left\{1 - \frac{\omega_{pe}^2}{\omega}\left(1 - \frac{\Omega_e}{\omega}\right)^{-1}\right\} \quad (4)$$

Growth Rate: The growth rate is obtained by solving the dispersion relation. Using asymptotic expansion for Z(**ξ**).Using the growth rate ($\frac{\gamma}{\Omega_e}$) formula[10].

$$\frac{\gamma}{\Omega_e} = \frac{\operatorname{Im} D(\omega, K)}{\Omega_e \frac{\partial}{\partial\omega}\{\operatorname{Re} D(\omega, K)\}} \quad (5)$$

$$\gamma = \sqrt{\pi}\frac{n_e}{n_i}\frac{\omega_{pe}^2}{K\Omega_e V_{T\Pi}}\frac{\left[\left(\frac{T_{\perp}^{(j+1)}}{T_{\Pi}} - 1\right)\frac{(\Omega_e - \omega)}{\omega} - 1\right]\exp\left(-\frac{\Omega_e - \omega}{K_{\Pi}V_{T\Pi}}\right)^2}{\frac{C^2K^2}{\omega^2} + \frac{n_e}{n_i}\frac{\omega_{pe}^2}{(\omega - \Omega_e)^2}} \quad (6)$$

Here it is noticed that j has affected the growth rate through the temperature anisotropy as discussed for the electromagnetic wave propagating parallel to the magnetic field with general loss cone distribution function.

Results and Discussion

The characteristics of the EMEC waves were derived the dispersion relation and growth rate by using plasma-pause region parameters[11].

B_0 = 500 nT , V_{TIIe}=6x10^{9}cm/s, , $\omega_{pe}{}^{+2}$= 159 x 10^9 s^{-2} ,Ω_e = 8.7 sec^{-2}

Figure 1 Shows the variation of wave frequency (ω) sec^{-1} versus wave vector (K_{11}) cm^{-1} for EMEC waves in magnetospheric plasma. It is observed that the frequency (ω) is linearly increases with the increasing of the parallel wave vector (K_{11}) cm^{-1} and the variation shows by the straight line on EMEC waves in plasma-pause region. The findings of the investigations may be of importance to the coronal heating and acceleration of solar wind by EMEC waves.

Figure 2 Predict the variation of the growth rate (γ) with the wave vector K_{II} (cm^{-1}) for different values of general loss cone distribution indices J =0, 1, 2, and 3 respectively. The steep-ness loss-cone distribution i.e. for the Maxwellian distribution the growth rate slightly decreases with the particular value of wave number (K_{II}). It is observed that the effect of increasing the growth rate transferred in the presence of general loss-cone distribution function J for the EMEC waves in the magnetospheric plasma. Steep loss-cone structures are analogous to mirror-like devices with a higher mirror ratio which may accelerate the charged particle moving along the magnetic field. Thus, a loss cone or ring velocity distribution is likely to drive ECH waves unstable, and the presence of the cold background electrons strongly affect the growth rates [2-7] which may explain the enhancement of such waves near the plasma pause.

Figure 3 Shows variation of growth rate (γ) of EMEC wave with respect to parallel wave vector ($K_{\|}$) for different values of temperature anisotropy A=0, 5, 10 and 15 respectively. Here it is noticed that growth rate is increases with wave vector ($K_{\|}$) for decreasing value of anisotropy A. It is assumed that the temperature anisotropy is directed from the ionosphere towards the magneto-tail. It is also observed that the effect of increasing the temperature anisotropy of EMEC waves is to enhance the growth rate rapidly.

It is found that the wave slow mode is resonant at the cyclotron frequency and it is strongly damped for wavelengths much shorter than the Debye length and the fast wave mode cut-off is above the electron cyclotron frequency and as values of wave number is increased from zero the damping rate increases maximum damping occurs at the wave number corresponding to the velocity of light divided by cyclotron frequency[1].

This study is to investigate the generation of (EMEC) Electromagnetic electron cyclotron waves in the magnetosphere and see the effect of general loss-cone distribution and temperature anisotropy in magnetospheric plasma. The kinetic approaches developed may be applicable to laboratory plasma as well as to estimate the heating rates, along with the study of emissions of EMEC waves.

Conclusion

In the present work, we have conducted a comprehensive mathematical analysis and found how an electromagnetic electron-cyclotron wave in plasma pause region may grow through the inverse Landau damping with temperature anisotropy. The effects of a general loss cone distribution with temperature anisotropy are also incorporated in the plamapause region to discuss EMEC wave's emission.

It is found that the effect of increasing general loss-cone distribution and temperature anisotropy enhance the growth rate of EMEC waves, may be due a shifting of the resonance condition. The growth rate increases with $K_{11,}$ attains a peak and decrease again in all cases. The behavior studied for the EMEC waves may be of importance in the electromagnetic emission. The result of the study is also applicable to the plasma devices that have the steep loss-cone distribution. The effect of general loss cone distribution with temperature anisotropy during the sub storm periods is to enhance the EMEC wave emission.

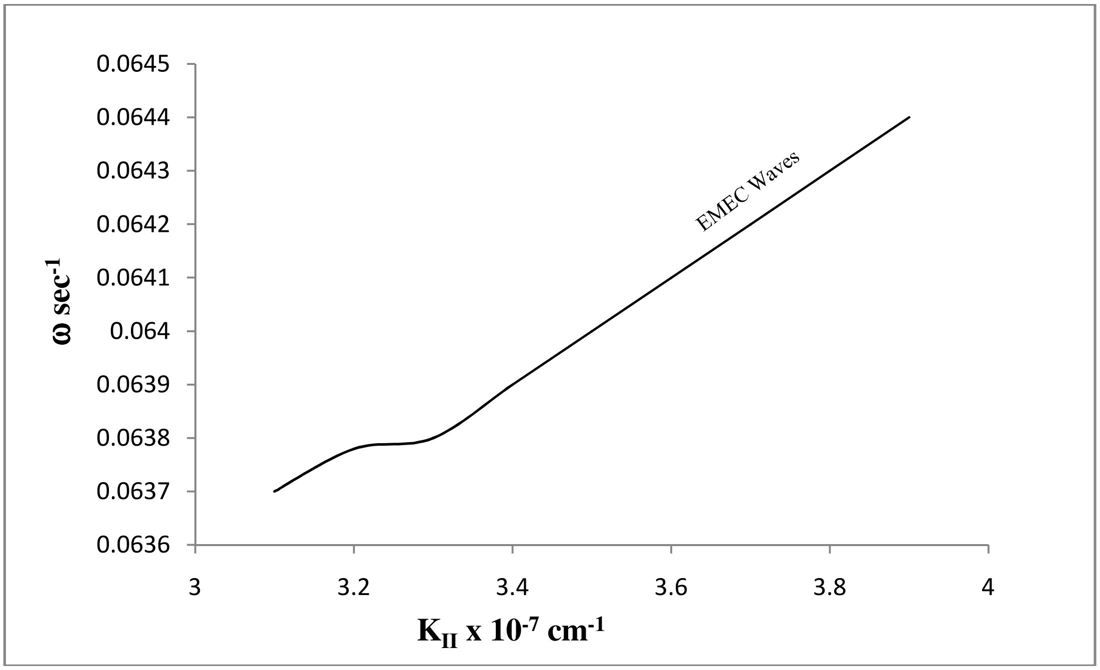

Figure-1
Variation of wave frequency (ω) sec^{-1} versus wave vector (K_{II}) cm-^{1} for EMEC waves

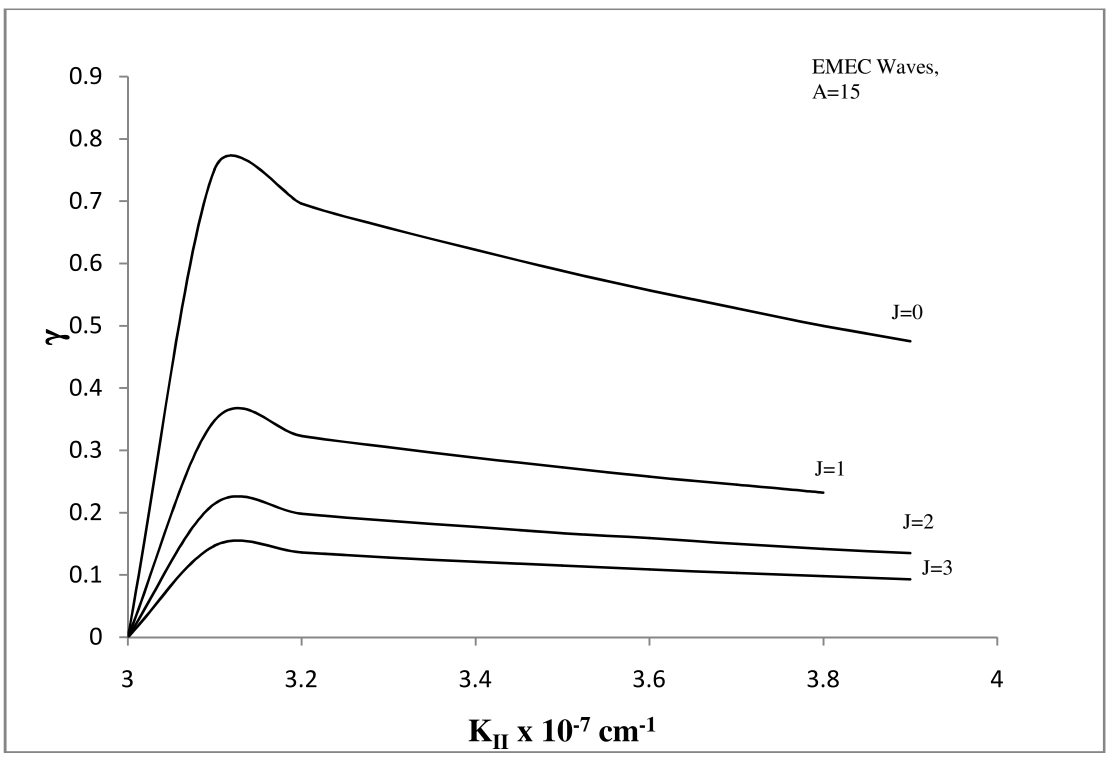

Figure-2
Variation of growth rate (γ) versus wave vector K_{II} cm^{-1} for different values of general loss-cone indices J

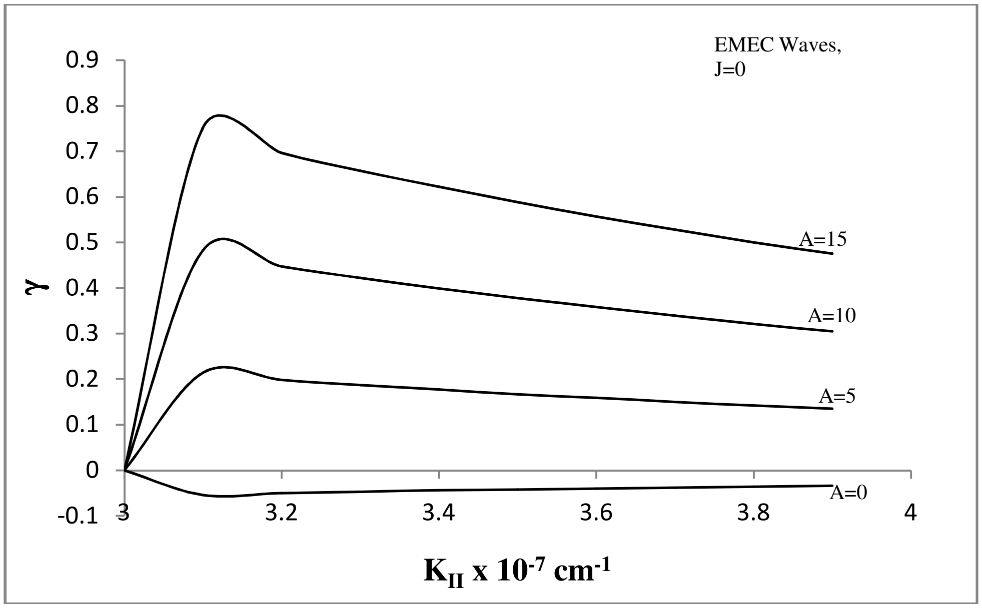

Figure-3
Variation of growth rate (γ) versus wave vector K_{II} cm^{-1} for different values of temperature anisotropy A

Acknowledgement

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