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Electromagnetic Ion-Cyclotron Waves in Saturn's Magnetosphere

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Abstract

Electromagnetic ion-cyclotron (EMIC) waves have been studied by single particle approach. The dispersion relation, growth rate of the electromagnetic ion-cyclotron waves in a low β (ratio of plasma pressure to magnetic pressure), homogeneous plasma have been obtained. The wave is assumed to propagate parallel to the static magnetic field. The effect of general loss-cone distribution function on EMIC waves is to enhance the growth rate. The results are interpreted for the Saturn magnetosphere has been applied to the magnetosphere Saturn to the observations made by Cassini parameters appropriate to the magneto-plasma.

Keywords: Electromagnetic ion-cyclotron waves, saturn's magnetosphere, solar plasma, general loss-cone distribution function.

Introduction

The geomagnetic micro-pulsations in the frequency range. 1-5 Hz have been explained by various workers in terms of ion-cyclotron instability arising due to the interaction of streaming proton and the left-hand circularly polarized electromagnetic wave. First results to the identify EMIC waves from our wave data, we focus only on emissions with a single clear peak in the electric field spectral density in the range 0.1 f_H+ - 0.5 f_H+ (48 - 216 Hz), where f_H+ is the proton gyro-frequency (≈400 Hz at the Freja altitudes).

Electromagnetic ion cyclotron (EMIC) waves have a clear peak in the power spectrum at frequencies below the proton gyro frequency, and they are often generated by precipitating electrons[1,2]. These waves are also believed to contribute to the ion energization[3].

The observations of the plasma wave spectrum observed at Saturn by Voyager 1 were first reported by Gurnett D.A. et al[4]. The first results from the Cassini Radio and Plasma Wave Science Instrument during the approach and first orbit around Saturn have been reported by Gurnett D.A., Kurth W. S., et. al.[5]. Observations of Saturn's magnetosphere gave access to its auroral, radio, UV, energetic neutral atom and dust emissions. Then, on July 1, 2004, Cassini Saturn Orbit Insertion provided us with the first in-situ exploration of Saturn's magnetosphere since 1 and 2 Voyager. The main advantage of this approach is to consider the energy transfer between wave and particles, along with the discussion of wave dispersion and the growth/damming rate of the wave. The method may be suitable to deal with the auroral electrodynamics where particle acceleration is also important along with wave emissions. The result obtained by this approach is the same as those derived using the kinetic approach.

The main objective of the present investigation is to examine the effect of general loss-cone distribution index *J* in view of the observations in Saturn magnetosphere has been applied to the magnetosphere Saturn to the observations made by Cassini. The present studies based on theory of Landau damping[6] which was further extended by Ahirwar G. et al.[7].

Cold Plasma Dispersion Relation

The existence of the ion energy anisotropy has been established and the growth is possible only when $\frac{V_{T\perp i}}{V_{T\amalg ci}} > 1.$ Thus we are interested in the behavior of those particles for which $\frac{V_{T\perp i}}{V_{T\amalg ci}} > 1.$ Then we consider the cold plasma dispersion relation for the EMIC wave[7] as:

$$\frac{c^2k^2}{\omega^2} = (\frac{\omega_p{}^2}{\Omega_i{}^2})(1 - \frac{\omega}{\Omega_i})^{-1} \tag{1}$$

Where $\omega_{pi}{}^2 = \frac{4\pi N_0 e^2}{m_i}$ is the plasma frequency.

Growth rate: Using the law of conservation of energy

$$\frac{d}{dt}(W_r + W_w) = 0 \tag{2}$$

The growth / damping rate γ is derived as[7]

$$\frac{\partial U}{\partial t} = 2\gamma U \tag{3}$$

Where $$\frac{dW_r}{dt} = -2\frac{\partial U}{\partial t}$$

and

$$\frac{dW_i}{dt} \sim \frac{\partial U}{\partial t}$$

Those particles with velocities near the phase velocity of the waves give up energy 2U to the waves. Half of this goes to potential energy and the other half goes into kinetic energy of oscillation of the bulk of the particles.

Hence the growth rate of EMIC waves is obtained as

$$\frac{\gamma}{\omega} = \frac{\frac{\Omega_i}{kV_{\amalg i}}[\frac{(\Omega_i-\omega)}{\Omega_i}\frac{(J+1)V_{T\perp i}^{2}}{V_{T\amalg i}^{2}}-1]\exp[-\frac{1}{V_{T\amalg i}^{2}}(\frac{\omega-\Omega_i}{k_{\amalg}})^2]}{(\frac{ck}{\omega_{pi}})^2(\frac{2\Omega_i-\omega}{\Omega_i-\omega})+\frac{1}{2}\frac{\omega^2}{(\Omega_i-\omega)^2}} \quad (4)$$

Results and Discussion

The role of the EMIC wave particle interaction in the Saturn's magnetosphere region is examined in the present analysis. Saturn magnetosphere has been applied to the magnetosphere Saturn to the observations made by Cassini[8].

Figure 1-3 predict the variation of the growth rate (γ) with the wave vector K_{II} (cm^{-1}) for different values of saturn raddi (*Rs*) and distribution index J = 0, 1, 2 and 3 respectively. The steepness of loss-cone distribution i.e. for the Maxwellian distribution the growth rate slightly increases with the particular value of wave number (K_{II}). It is observed that the effect of increasing the Saturn radii (*Rs*) with distribution index is to enhance the growth rate.

Distance	n_c (cm^{-3})	T_c (ev)	B_0 (nT)
R~ 5.5 Rs	14	20	100
R~ 3.9 Rs	30	20	300
R~ 2.2 Rs	100	20	1400

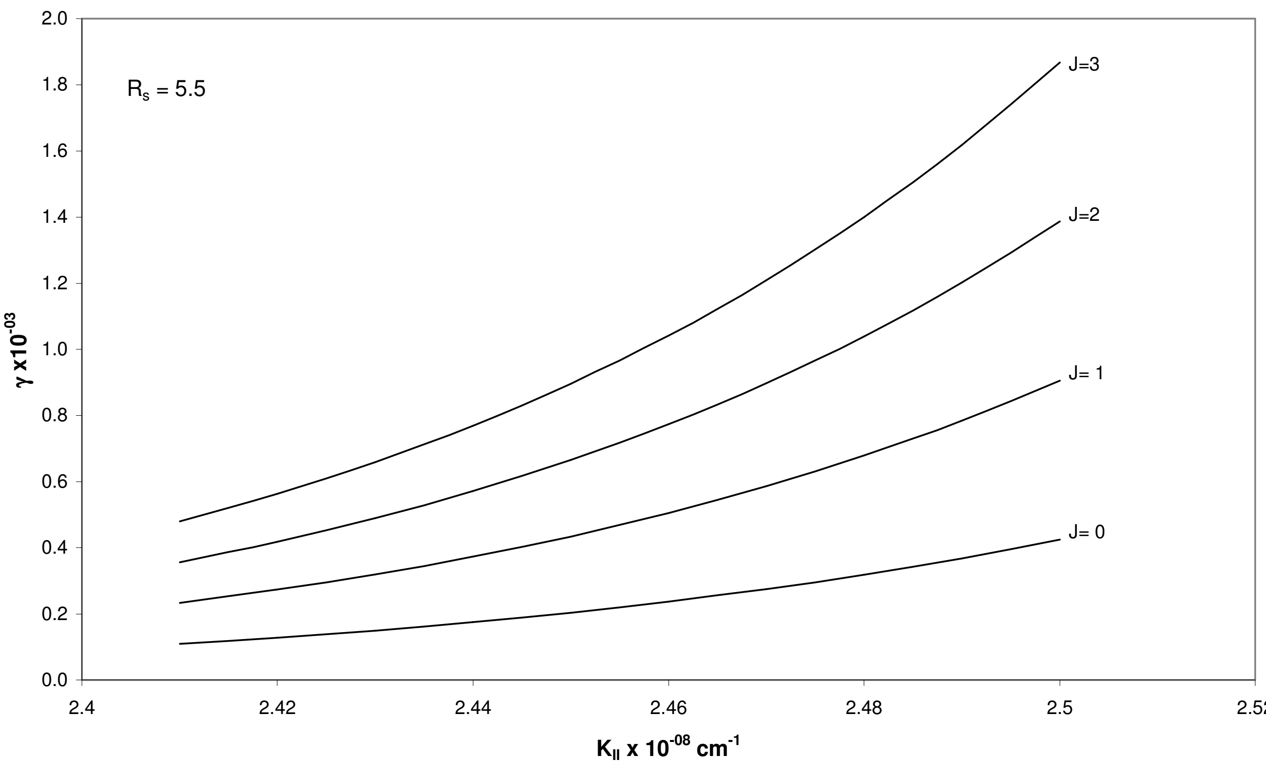

Figure-1
Variation of growth rate (γ) versus wave vector K_{II} (cm^{-1}) for different values of distribution indices J at R_s =5.5

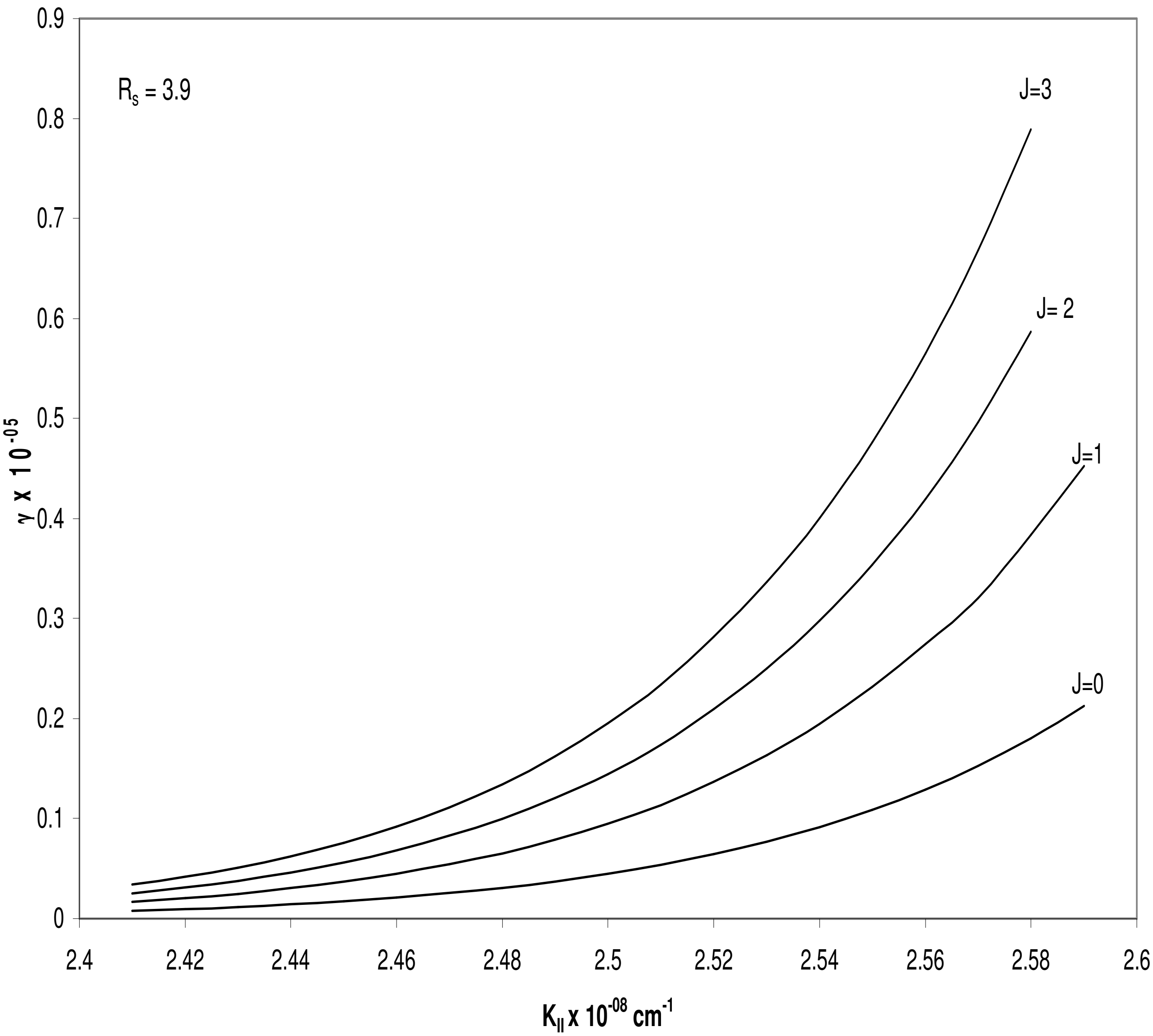

Figure-2
Variation of growth rate (γ) versus wave vector K_{II} (cm^{-1}) for different values of distribution indices J at R_s =3.9

Conclusion

In the present work, we have study of an electromagnetic ion-cyclotron wave in saturn's magnetospheric plasma. It is found that the growth rate enhance with effect of general loss-cone distribution with increase the saturn's radii of explain the waves emission.

The effect of increasing steepness general loss-cone distribution function on electromagnetic ion cyclotron waves is to enhance the growth rate, may be due a sub-storm phenomena. The growth rate increases with $K_{11,}$ attains a peak and decrease again in all cases. The interpreted may be applicable to explain the ion heating in the solor wind as well as auroral acceleration region.

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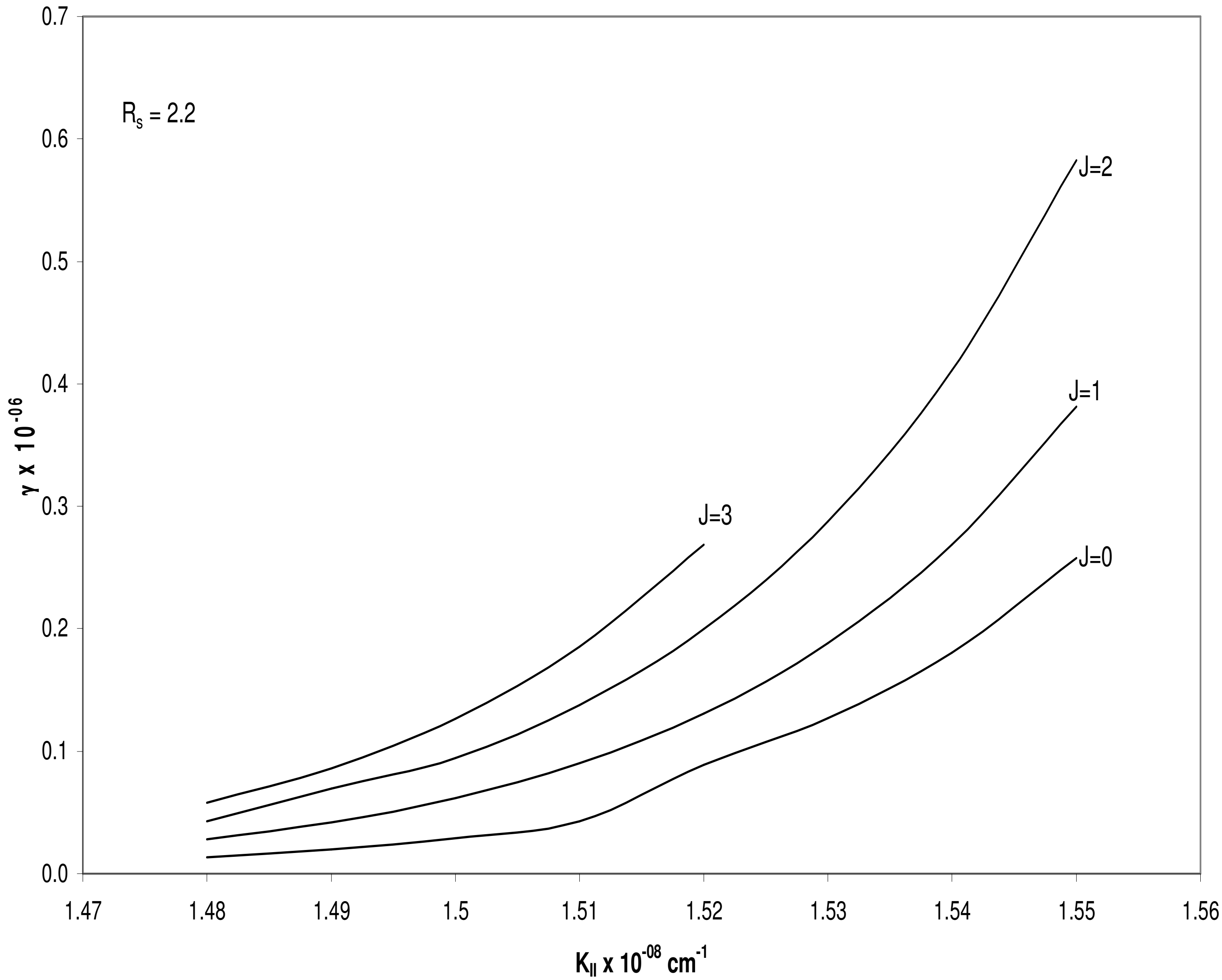

Figure-3
Variation of growth rate (γ) versus wave vector K_{II} (cm^{-1}) for different values of distribution indices J at R_s =2.2

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