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Alfven Waves in the Presence of Parallel Electric Field in Saturn's Magnetosphere-Particle Aspect Approach

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Abstract- In this paper, we have derive the dispersion relation, and growth rate of Alfven wave in the presence of parallel electric field in Saturn magnetosphere has been applied to the magnetosphere Saturn to the observations made by Cassini.s. The effect of parallel electric field is included in the zeroth order distribution function through modification of the electron thermal velocity parallel to ambient magnetic field. It is found that the parallel electric field of the electrons enhances the damping/growth rate of the wave according to the direction of electric field. The applicability of theory for the space plasma has been discussed.

Index Terms- Alfven waves, Saturn's magnetosphere region, Solar plasma, Plasma density, Parallel electric field, Thermal velocity.

I. Introduction

Alfve'n waves play an important role in energy transport, in driving field-aligned currents, particle acceleration and heating, inverted–V structures in magnetosphere-ionosphere coupling, solarflares and the solar wind. The S3-3 satellite mission established that auroral acceleration is a near earth process, often less than 8000 km in altitude. Subsequent missions verified this finding. FAST observation also suggests both high and low- altitude acceleration regions [1]. The polar observations now conclude that the majority of auroral acceleration is below 2 R_E in altitude [2]. The ionosphere and magnetosphere are electro-dynamically coupled by electric field and the existence of electric fields therein significantly changes the electrodynamics energization and transport of charged particles in both the regions [3].

The large parallel electric field structure associated with ion cyclotron waves in the upward currents region were seen in association with an ion beam [4].The observations of the plasma wave spectrum observed at Saturn by Voyager 1 were first reported by [5].

In this study, we have review selected fundamental plasma processes that control the extensive space environment, or magnetosphere, of Saturn's. This writing occurs at a point in time when some measure of maturity has been achieved in our understanding of the operations of Saturn's magnetosphere and its relationship to those of Earth.

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 main objective of the present investigation is to examine the effect of parallel electric field with temperature anisotropy in view of the observations in Saturn magnetosphere has been applied to the magnetosphere Saturn to the observations made by Cassini.

II. DISPERSION RELATION

To evaluate the dispersion relation, we use the Maxwell's equation as:

$$\frac{\omega^2}{K_\Pi{}^2} = (V_A{}^2 - V^2_{T\Pi ce})(1-\frac{V_A{}^2}{C^2})^{-1} \qquad (1)$$

In the presence of parallel electric field the dispersion relation of the Alfve'n wave is changes as:

$$\frac{\omega^2}{K_\Pi{}^2} = (V_A{}^2 - V^2_{T\Pi ce})(1+\frac{V_A{}^2}{C^2}) \qquad (2)$$

Where $V_{T\Pi ce} = (1+\frac{ieE_0}{mK_\Pi V^2_{T\Pi e}})^{1/2}.V_{T\Pi e}$.

The dispersion relation reduces to well known expression of dispersion relation $\omega = K_\Pi V_A$ for Alfven waves when $V_{T\Pi} = 0$ and V_A<<C. Here $V_A = B_0/(4\pi N_0 m_i)^{1/2}$ is the Alfven velocity.

III. GROWTH RATE

Substituting the values of complex frequency $\omega = \omega_r + i\gamma$ and thermal velocity $V_{T\Pi ce} = (1+\frac{ieE_0}{mK_\Pi V^2_{T\Pi e}})^{1/2}.V_{T\Pi e}$ in the dispersion relation and separating the real and imaginary part, we evaluate the real frequency and growth / damping rate of Alfven wave as:

$$\frac{\omega_r{}^2}{k_\Pi{}^2} = [V_A{}^2 - V^2{}_{T\Pi e}](1+\frac{V_A{}^2}{C^2}) \qquad (3)$$

and

$$\gamma = -\frac{eE_0}{m}.\frac{K_\Pi}{2\omega}(1+\frac{V_A{}^2}{C^2}) \qquad (4)$$

Here we notice that the dissipation and growth of Alfven wave depends upon the direction of parallel electric field E_0. The upward electric field generates the wave whereas downward electric field dissipates the wave.

IV. RESULTS AND DISCUSSION

We have evaluated the dispersion relation and growth/damping rate of Alfven wave in the presence of parallel electric field using the following parameters for Saturn's magnetosphere. [7].

Distance	n_c (cm^{-3})	T_c (ev)	B_0 (nT
R~ 5.5 R_s	14	20	100

Fig. 1 Shows the variation of frequency of plasma (ω) in sec^{-1} versus wave vector (k_{11}) in cm^{-1} for Alfven waves in Saturn's magnetosphere plasma. It is found 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.

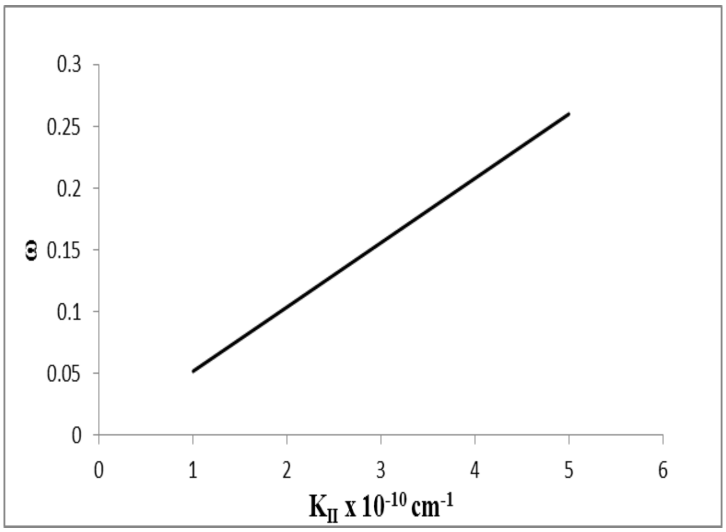

Fig. 1 Variation of wave frequency (ω) versus wave vector (K_{II}) cm^{-1}.

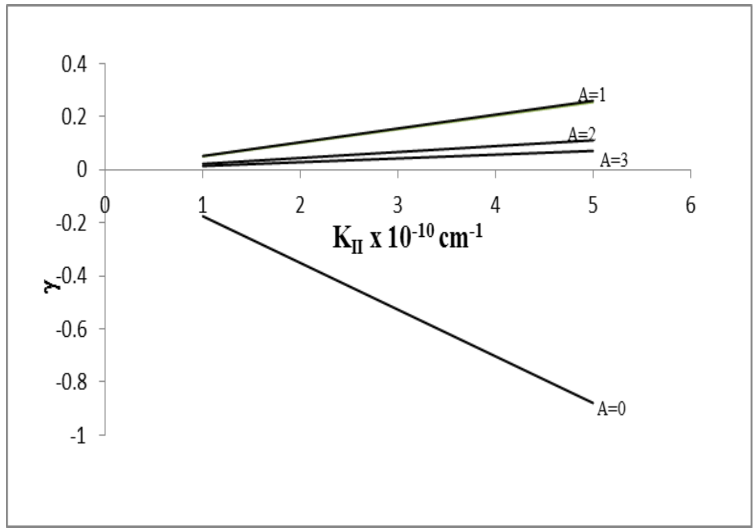

Fig. 2 Variation of growth rate (γ) versus wave vector (K_{II}) cm^{-1} for different values of temperature anisotropy A at 5.5Rs.

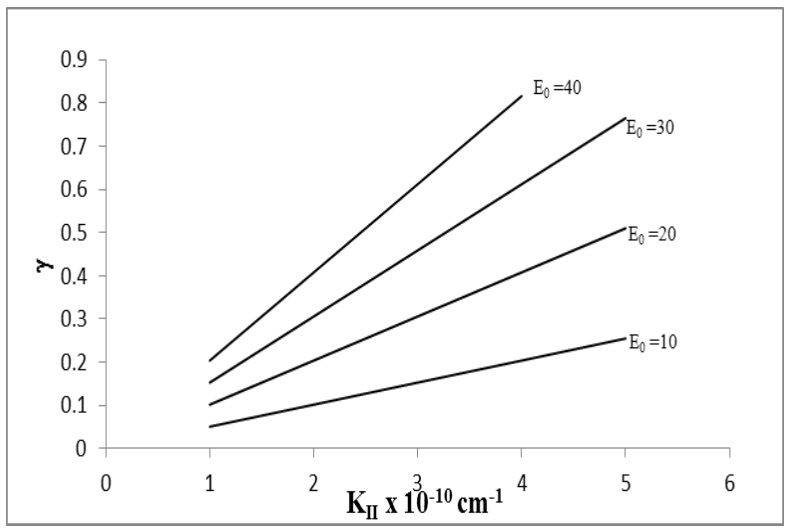

Fig. 3 Variation of growth rate (γ) versus wave vector (K_{II}) cm^{-1} for different values of parallel electric field E0 at 5.5 Rs.

Fig. 2 predict the variation of the growth rate (γ) with the wave vector (k_{11}) cm^{-1} for the different values of temperature anisotropy A. It is observed that the graph the peak of the growth rate which shifts towards the lower side of the parallel wave vector (k_{11}) then, the growth rate is also decreases. The increasing of the growth rate transferred in the presence of thermal anisotropy for the Alfven waves in the Saturn's magnetosphere plasma.

Fig. 3 Depict the variation of growth rate (γ) with the wave vector (k_{11}) cm^{-1} for different values of parallel electric field E_0. It is also observed that the effect of increasing the parallel electric field is to enhance the growth rate rapidly.

V. Conclusions

In the present work, we have conducted a comprehensive mathematical analysis and found how an Alfven waves in Saturn's magnetosphere plasma may grow through the inverse Landau damping. The effects of parallel electric field with thermal anisotropy are also incorporated in the Saturn's region to discuss Alfven wave's emission.

The concluding remarks of this study are as follows:

1. It is found that the effect of thermal velocity is to enhance the growth rate of Alfven 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.
2. The effect of increasing the values of parallel electric field, increases with K_{11} is to increase the growth rate of Alfven waves.
3. The findings may be applicable to explain the Alfven wave's in the solor corona as well as Saturn's magnetosphere region and the acceleration of the solar wind.

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