ABSORPTION OF ELECTROMAGNETIC WAVES IN ASTROPHYSICAL PLASMAS

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ABSTRACT: We study Parametric Decay Instabilities(PDI) using the kinetic description, in the homogeneous and unmagnetized plasmas. These instabilities cause anomalous absorption of the incident electromagnetic (e.m)radiation. The maximum plasma temperatures reached are functions of luminosity of the non-thermal radio radiation and the plasma parameters.

1. INTRODUCTION

Quasars, seyfert galaxies and pulsars are among the most luminous objects and emit strongly at radio frequencies. Plasma clouds of electron density $10^4 \le n_e \le 10^{10}\,cm^{-3}$ exist in their atmosphere. The conditions for PDI are known to be satisfied in the emission line regions (Krishan 1987). We extend the study of PDI in the entire range of plasma and pump parameters.

2. PARAMETRIC DECAY INSTABILITIES.

The incident e.m pump wave (ω_0, K_0) excites a high frequency electron plasma wave (ω_e, K_e) and a low frequency ion-acoustic wave (ω_i, K_i) such that $\omega_0 = \omega_e + \omega_i$ and $K_0 = K_e + K_i$. The PDI can be described using the dispersion relation (Liu & Kaw 1976)

$$\frac{1}{\chi_e} + \frac{1}{\chi_i + 1} = -(K.V_0)^2 \left[\frac{1}{(\omega-\omega_0)^2\, \varepsilon(K,\omega-\omega_0)} + \frac{1}{(\omega+\omega_0)^2\, \varepsilon(K,\omega+\omega_0)} \right] \quad \text{..........(1)}$$

Where $\chi_e(K,\omega)$ & $\chi_i(K,\omega)$ are electron & ion susceptibilities respectively. ε is the dielectric function. $v_0 = eE_0/m_e\omega_0$ is the oscillation velocity of electrons in the pump field E_0. $E_0 = (L/Rc^2)^{1/2}$: $L = L_{41} \times 10^{41}$ erg/sec and $R = r_{pc} \times 3.10^{18}$ cm are the luminosity and distance between the source and plasma respectively. We assume $k_e \simeq k_i \simeq K$, $k_0 \simeq 0$ and $\omega_0 \simeq \omega_e + \omega_i$. Consider $k\lambda_{De} \ll 1$, $\omega_{pi} \gg \omega_i \simeq kc_s$, and neglecting $\varepsilon(K, \omega+\omega_0)$ as being off-resonant. ω_{pe} & ω_{pi} are electron & ion plasma frequencies respectively. λ_{De} is the Debye length. c_s is the ion acoustic velocity.

E. R. Priest and V. Krishan (eds.), Basic Plasma Processes on the Sun, 519–520.

The equation (1) is solved for $kv_e \gg \omega \geq kv_i$ & $\omega = \omega_r + i\gamma$ using $k=3\times10^{-3}\,cm^{-1}$ & $n_e=10^{6}\,cm^{-3}$.

When $\omega_0 > \omega_{pe}$, pump e.m wave excites a electron plasma wave and a (I) ion-acoustic wave. (curve 1 in figs 1,2 & 3) We found for $L41 \leq 10^{2}$ & Ti=Te/20, the growth rate $\gamma \ll \omega_s \simeq kc_s$. At lower $Te \leq 6\times10^{6}$ K collisional damping dominates which decreases with increasing Te and therefore threshold luminosity L41t decreases. For $Te \geq 10^{7}$ K Landau damping takes over and therefore L41t increases. But for $6\times10^{6} \leq Te \leq 3\times10^{7}$ K nither collisional nor Landau damping is significant & hence minimum L41t is needed.

(II) reactive quasi-ion mode. (curve 2 in figs 1,2 & 3) For $L41 \geq 10^{2}$ ion mode grows largely: $\omega = \omega_r + i\gamma$, $\gg kc_s$ & the ratio $\gamma/\omega_r \to 3^{1/2}$.

(III) resistive quasi-ion mode. (curve 3 in figs 1,2 & 3) This mode excites when $T_e \leq T_i$: Te=Ti/10. Since $c_s \simeq v_i$, ion mode under goes large nonlinear Landau damping. Therefore this mode excites at large L41.

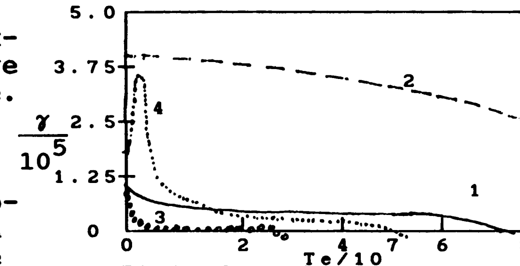

Fig1. Growth rate of PDI's

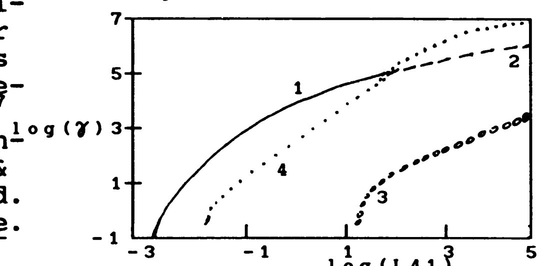

Fig2. Growth rate of PDI's

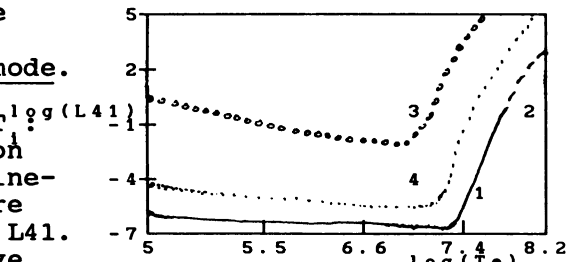

Fig3 PDI's threshold luminosity vs electron temperature Te.

When $\omega_0 < \omega_{pe}$, pump e.m wave excites electron plasma wave & a non-oscillating ion mode. This case of PDI is known as oscillating two-stream instability. (curve4 in figs 1,2 & 4).

Results and Conclusions.

1) Growth rates are maximal when $K \parallel E_0$ and negative for $K \perp E_0$.

2) The absorption rate of e.m wave (rate of PDI) is proportional to the ratio $L41/rpc^{2}$ and it is much larger than the free-free absorption rates. 3) T_e increases by a factor of several tens for moderate radio luminosities.

Decay instability may be the mechanism for the formation of hot lower density corona adjoining each photoionized dense region. In the case of quasars, the radio luminosity is found to be less thqn that expected from the extrapolation of the spectrum from high frequencies to low frequencies. Therefore absorption is certainly there and anomalous absorption might modify the spectrum in a significant way.

Referrences.

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