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**A METHOD OF ESTIMATING THE LEVEL OF COLLECTIVE ELECTRIC FIELD FLUCTUATIONS IN A NONTHERMAL PLASMA WITH A TWO-TEMPERATURE ELECTRON GAS**

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Introduction

The time averaged spectral energy density of electrostatic waves in a nonthermal plasma is one of the main ingredients which enter into a calculation of transport coefficients including collective effects. Regarding a bimaxwellian electron distribution function /1/, characterized by the parameters  $T_>/T_< \gg 1$  and  $(1-\beta) = n_</n_>$  ( $T_<$ ,  $n_>$  are the temperature and the density of the thermal electrons;  $n_<$ ,  $T_>$  refer to the superthermal electrons), a strong enhancement of the level of electric field fluctuations at a frequency slightly above the electron plasma frequency is expected. Considering the HF conductivity this should give rise to marked effects compared with the thermal case /2/. Furthermore, it is suggested, that in the Stark broadened profiles of emission lines the vicinity of the electron plasma frequency is strongly emphasized even in the case of an extremely low density of superthermal electrons /3/. This would imply that the appearance of the so-called plasma satellites represents a sensitive indicator of a superthermal electron component. Nevertheless, a critical discussion of the real diagnostic possibilities requires a study of the effects in a wide range of parameters. Without considerably increasing the numerical efforts this may be achieved only by means of a simple approach incorporating the main features of the theory.

Basic equations

We start from the following expression for the energy density of collective electric field fluctuations

$$(1) W = C \cdot \int_0^\infty G(\Omega) d\Omega \quad C = \frac{e^2 n_>}{\pi v_{th} \omega_p}$$

$G(\Omega)$  is the spectral energy density written in dimensionless variables as in ref. 2:

$$(2) G(\Omega) = \int_{x_D}^\infty \frac{dx \sqrt{\pi} \{ \beta e^{-\Omega^2 x^2} + (1-\beta) \sqrt{\frac{T_<}{T_>}} e^{-\Omega^2 x_1^2} \}}{x \cdot \{ |\epsilon(x, x_1, \Omega, \beta)|^2 \}}$$

Here the following notations are used

$$\omega_p = \left\{ \frac{4\pi n_> e^2}{m} \right\}^{1/2} ; v_{th}^2 = \frac{k T_<}{m}$$

$$\Omega = \frac{\omega}{\omega_p} ; x = \{ \sqrt{2} k \lambda_D \}^{-1} ; x_1 = \sqrt{\frac{T_<}{T_>}} x$$

$$x_D = 1/\sqrt{2} ; \lambda_D \text{ is the Debye length} = \frac{V_{th}}{\omega_p}$$

The integrand of equation (2) is essentially determined by the zeroes of the real part of the dielectric constant  $Re(\epsilon)$ . In the case of resonance the dielectric constant in the denominator may be replaced by the Landau damping decrement  $Im(\epsilon)$  (binary collisions are not included in this treatment). For a given  $\Omega$  the resonance is localized at  $x_{RES} > x_D$  which is determined from  $Re(\epsilon) = 0$ . In this connection it is sufficient to use the Bohm-Gross relation for an estimate. Moreover, we realize that the following approximation holds for  $\Omega \geq 1$ :

$$(3) G(\Omega) \approx K \cdot \frac{2\Omega^4}{3} x_{RES}^3 \cdot Im\{\epsilon(\Omega, x_{RES})\} F(\Omega, x_{RES})$$

where  $F(\Omega, x_{RES})$  is the integrand of equation (2) in the case of resonance. This approximation follows from a Taylor expansion of  $Re(\epsilon)$  around  $x_{RES}$ . The width of the resonance is proportional to the extension of the region where  $Im(\epsilon) > Re(\epsilon)$ . In the most interesting cases it can be shown that in the vicinity of  $x_{RES}$   $Im(\epsilon)$  varies slowly compared with  $Re(\epsilon)$ .  $K = 1.3$  is obtained by evaluating equation (2) numerically in a rigorous way. This evaluation was carried out by using two different sets of parameters: (a) the same as in ref. 3, Fig. 2; (b)  $T_>/T_< = 40$ ,  $(1-\beta) = 10^{-4}$ . Applying the approximative equation (3) the numerical integration in equation (1) can be easily performed.

Results

Fig. 1 shows the electric field strength  $E_0 = (8\pi W)^{1/2}$  as a function of the para-

meters  $T_>/T_<$  and  $(1-\beta) = n_</n_>$ .

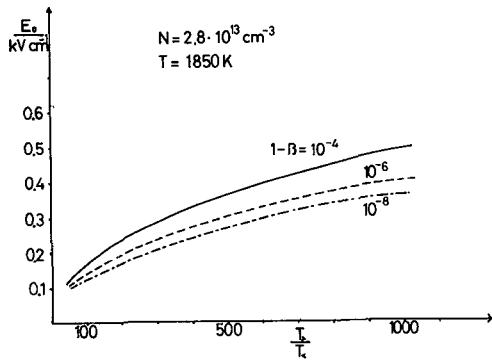


Figure 1:  $E_0 = (8\pi W)^{1/2}$  vs.  $T_>/T_<$  for different values of  $n_</n_>$

The quoted plasma parameters referring to the bulk of thermal electrons enter only into the factor C of equation (1). Therefore it is not difficult to transfer these results to other plasma parameters. An example shall illustrate the application of the foregoing considerations. The influence of collective electric field fluctuations upon the wings of Stark broadened hydrogen lines is characterized by the ratio U, which is given by the intensity  $I_{nth}$  in the nonthermal case divided by the intensity  $I_{th}$  in the thermal case ( $\beta=1$ ):

$$(4) U = \frac{I_{nth}}{I_{th} \omega = \omega_p} = 1 + \frac{8}{3\pi} \frac{d^2 e^2 n_>}{h^2 v_{th} \omega_p C} \frac{W}{I_{th}(\Delta\omega = \omega_p)}$$

d is the electric dipole moment (see eq. (9) of ref. 4), h Planck's constant and P(o) the central intensity, which results from a folding of all broadening mechanisms with the exclusion of the electron impact broadening. Fig. 2 shows U as a function of  $T_>/T_<$  and  $(1-\beta)$ . Here the example of the line  $P_\alpha$  is chosen. The plasma parameters are the same as in Fig. 1. The detection threshold refers to the special conditions of a low density plasma, which is described in ref. 5.

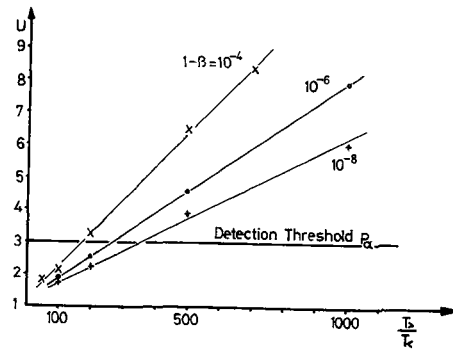


Figure 2: Enhancement of the wing intensity of the hydrogen line  $P_\alpha$  produced by collective effects ( $\Delta\omega \approx \omega_p$ )

Conclusions

This study presents an easy method of estimating to which extent collective phenomena must be taken into consideration in the case of a bimaxwellian electron distribution. Concerning e.g. the Stark broadening of spectral lines it is shown that contrary to former conclusions there are no dramatic effects in reality. Only in extreme situations a detectable influence due to nonthermal electrons upon the line shape can be expected.

Acknowledgement

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References

- 1 D. A. Tidman, T. H. Dupree, Phys. Fluids 8, 1860 (1965)
- 2 J. Dawson, C. Oberman, Phys. Fluids 5, 517 (1962)
- 3 W. R. Chappell, J. Cooper, E. W. Smith, J.Q.S.R.T. 10, 1195 (1970)
- 4 H. Griem, Ap. J. 147, 1092 (1967)
- 5 H. Schlüter, Z. Naturforschung 18a, 439 (1963)