

Electrostatic waves in inhomogeneous pair-ion plasma

J. Vranjes*, B. P. Pandey† and S. Poedts **

*Center for Plasma Astrophysics, Celestijnenlaan 200B, 3001 Leuven, Belgium, and Faculté des Sciences Appliquées, avenue F.D. Roosevelt 50, 1050 Bruxelles, Belgium

†Department of Physics, Macquarie University, Sydney, NSW 2109, Australia

** Center for Plasma Astrophysics, and Leuven Mathematical Modeling and Computational Science Center (LMCC) Celestijnenlaan 200B, 3001 Leuven, Belgium

Keywords: Pair ion plasma, waves, instabilities

PACS: 52.27.Cm; 52.30.Ex; 52.35.Fp

In the recent past there has been a lot of activity in the theory and experiments dealing with plasmas containing positive and negative ions of equal mass and opposite charge, all initiated in a recent series of works [1] describing experimental production of pair ions C_{60}^{\pm} . In the present work we discuss the effects of the density gradient in the direction perpendicular to the ambient magnetic field vector, that have been observed in the experiments. A possible presence of electrons, that may enter the plasma attached to negative ions, is also discussed in the context of plasma modes propagating at an angle with respect to the magnetic field vector. It is shown [2] that the electron plasma mode in a cold plasma may become backward in the presence of the density gradient, and this behavior (described in Fig. 1.) may be controlled either by the electron number density or the mode number in the perpendicular direction. A backward solution $\partial\omega/\partial k_z < 0$, is obtained by taking $B_0 = 0.1$ T, $L_n = n_{e0}/n'_{e0}$, where $n_{e0}(r) = N_0 \exp(-r^2/a^2)$, so that locally $|L_n| = a^2/(2r)$. If $a = r_0$, or $a = 2r_0$, where $r_0 = 4$ cm is the plasma radius, at $r = r_0$ this gives for the density 0.37 and 0.78 times its value at the axis, respectively. We choose $L_n = 8$ mm, and take three values for the plasma number density: $n_0 = 10^{16} \text{ m}^{-3}$, $n_0 = 5 \cdot 10^{15} \text{ m}^{-3}$, and $n_0 = 10^{15} \text{ m}^{-3}$.

In plasma with hot electrons an instability may develop, driven by the combination of electron collisions and the density gradient, and in the regime when the ions response is similar to a sound mode (un-magnetized ions, mode frequencies much above the ion gyro-frequency or mode wave-lengths shorter than the ion gyro-radius). The dispersion equation becomes:

$$1 = \frac{\omega_{pa}^2}{\omega^2 + i\omega v_a - k^2 v_{Ta}^2} + \frac{\omega_{pb}^2}{\omega^2 + i\omega v_b - k^2 v_{Tb}^2}$$

$$- \frac{1}{k^2 \lambda_e^2} \frac{\omega_* - v_{Te}^2 k_z^2 [1 - \alpha \omega_1 \omega_\alpha k_y^2 / (k_z^2 \Omega_e^2)] / \omega_1}{\omega - v_{Te}^2 k_z^2 [1 - \alpha \omega_1 \omega_\alpha k_y^2 / (k_z^2 \Omega_e^2)] / \omega_1}, \quad \omega_\alpha = \omega_0 \alpha + i v_e, \quad \alpha = \frac{1}{1 + v_e^2 / \Omega_e^2}. \quad (1)$$

Here, $\omega_* = -k_y \kappa T_e n'_{e0} / (e B_0 n_{e0})$, $\omega_0 = \omega - k_y v_{e0}$. For the pair-ion electron plasma, Eq. (1) is solved for collision-less ions in terms of n_{b0}/n_{a0} , and the result for the acoustic

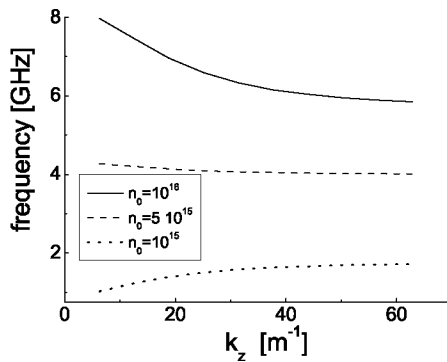


FIGURE 1. Transition from direct to backward mode.

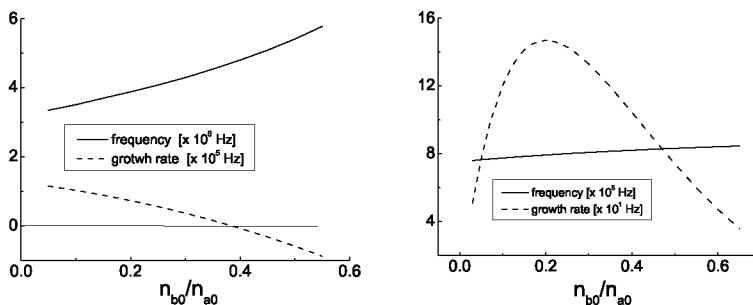


FIGURE 2. Left: the solution of Eq. (1) for a modified ion acoustic mode as a function of the negative-ion number density, for equal temperatures of the two ion species. Right: additional acoustic mode from Eq. (1) in the case of different temperatures of positive and negative ions, for $T_a = 0.5$ eV, and $T_b = 0.3$ eV.

mode is presented in Fig. 2 (left). In the case of different temperatures of two pair-ion species, there appears an additional acoustic mode presented in Fig. 2 (right).

Acknowledgements: results obtained in the framework of the projects G.0304.07 (FWO-Vlaanderen), C 90205 (Prodex), GOA/2004/01 (K.U.Leuven), and the Interuniversity Attraction Poles Programme - Belgian State - Belgian Science Policy.

REFERENCES

1. W. Oohara and R. Hatakeyama, Phys. Rev. Lett. **91**, 205005 (2003); *id.* **95**, 175003 (2005).
2. J. Vranjes, D. Petrovic, B. P. Pandey, and S. Poedts, *Phys. Plasmas*, in print.

Copyright of AIP Conference Proceedings is the property of American Institute of Physics and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.