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Threshold electron drift for the spontaneous excitation of non-electrostatic ion-cyclotron oscillations in weakly ionized plasmas

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Ion-cyclotron oscillations in plasmas are generally treated as electrostatic in most theories, although it is obvious that they are of non-potential character. In this paper an attempt is made, therefore, to investigate some outstanding characteristics of these oscillations, assuming that they are not electrostatic. A uniform and infinite weakly ionized plasma is considered, and it is assumed to be placed in a homogeneous and static B, parallel to a constant d.c. E0. The ensuing anomalous Doppler effect eventually gives rise to ion- and, of course, also electron- cyclotron waves of growing amplitude. This fact of spontaneous excitation has been long ago observed experimentally and the value of the threshold drift for the spontaneous excitation considered here. The approximate expressions for this function are different at $z_1 \ll 1$ and at $z_1 \gg 1$ (respectively, long-wave and short-wave limits, with respect to Larmor radius). It has been found that in the long-wave limit, the temperature dependence (appearing through the collision frequencies, thermal velocities and the variable $z_1$) of the threshold electron drift for the spontaneous excitation of the $m^{th}$ harmonic of the non-electrostatic ion-cyclotron oscillations is:

$$\frac{\mu_0}{\nu_i} \sim \frac{k_i^2 \nu_i}{E_0} \frac{2 - z_1}{1 + \omega_{pi}^2 \nu_i^2} \frac{\nu_i}{\nu_0} \chi(z_1).$$

where $\chi(z_1)$ is a rather complicated function of the argument $z_1 = k_i^2 \nu_i / E_0$ ($\xi_i$ being the ion Larmor radius), which describes the effects of finite Larmor radius in the process of spontaneous excitation considered here. The approximative expressions for this function are different at $z_1 \ll 1$ and at $z_1 \gg 1$ (respectively, long-wave and short-wave limits, with respect to ion Larmor radius). It has been found that in the long-wave limit, the temperature dependence (appearing through the collision frequencies, thermal velocities and the variable $z_1$) of the threshold electron drift for the spontaneous excitation of the $m^{th}$ harmonic of the non-electrostatic ion-cyclotron oscillations is:

$$\frac{\mu_0}{\nu_i} \sim \frac{k_i^2 \nu_i}{E_0} \frac{2 - z_1}{1 + \omega_{pi}^2 \nu_i^2} \frac{\nu_i}{\nu_0} \chi(z_1).$$

In the short-wave limit, on the contrary, the threshold drift in question is practically independent of the order of the harmonic $m$, and it is much larger than in the former case. It is given by:

$$\frac{\mu_0}{\nu_i} \sim \frac{k_i^2 \nu_i}{E_0} \frac{2 - z_1}{1 + \omega_{pi}^2 \nu_i^2} \frac{\nu_i}{\nu_0} \chi(z_1).$$

Hence, in both short- and long-wave limits, a temperature dependence of the form $\nu_i^{12}$ is found. This is in accordance with the behaviour found in [2], which suggests that the waves excited in that experiment were not electrostatic. It would be of interest to observe experimentally the $T_i$-dependence of the threshold drift in the long-wave limit it should be a function of $m$, according to the theory developed here.

References