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Two fluid instability in extremely low density plasma

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The extremely low plasma with very strong magnetic field is expected to exist in some regions in the universe, for example, near the pole of the black hole of the active galactic nuclei (AGNs), like in the AGN of the elliptic galaxy M87[1]. If the strong magnetic field includes anti-parallel magnetic field, the significant electric current sheet is required to sustain the anti-parallel magnetic field. In the extremely low density plasma, the drift velocity of the charged particles, v_0, that carry the current, is extremely large and the drift motion of the charged particles may be unstable. This instability is well known as the 'two fluid instability' [2], but the stability condition is not shown in a simple form yet.
Here, we show the linear analysis of the instability using the two fluid equation of the plasma with finite temperature. We obtained the following equation of the dispersion relation,

$$F(\omega) = \frac{m}{\omega^2 - c_i^2 k^2} + \frac{M}{(\omega - v_0 k)^2 - c_e^2 k^2} = \frac{m+M}{\omega_p^2}$$

where m and M are masses of electron and positively charged particle, ω is the angular frequency, k is the wave number, c_i is the sound speed of the positively charged fluid, c_e is the sound speed of the electron fluid, ω_p is the plasma frequency of the normal plasma. $F(\omega) = \frac{m+M}{\omega_p^2}$ is the quartic equation, which has four solutions. The function $F(\omega)$ has two types of profile, in the cases of $c_i + c_e > v_0$ and $c_i + c_e \le v_0$. For simplicity, we show the profile of $F(\omega)$ of the electron-positron pair plasma in Figure 1. In the case of $c_i + c_e > v_0$, Figure 1 clearly shows that equation $F(\omega) = \frac{m+M}{\omega_p^2}$ has four real solutions which indicates the current is stable. On the other hand, in the case of $c_i + c_e \le v_0$, $F(\omega) = \frac{m+M}{\omega_p^2}$ has only two real solutions and other two solutions are complex, which indicates that the current is unstable. This linear analysis yields the criterion of the electric current instability. In the extremely low density plasma, the current may become unstable due to the two fluid instability. This instability may be important for the plasma supply mechanism of the relativistic jet from the AGN. In our talk, we present the details of the linear analysis of the normal plasma and further aspects. To apply this mechanism for the astrophysical situation, it is required to perform numerical simulations with two fluid approximation.

References

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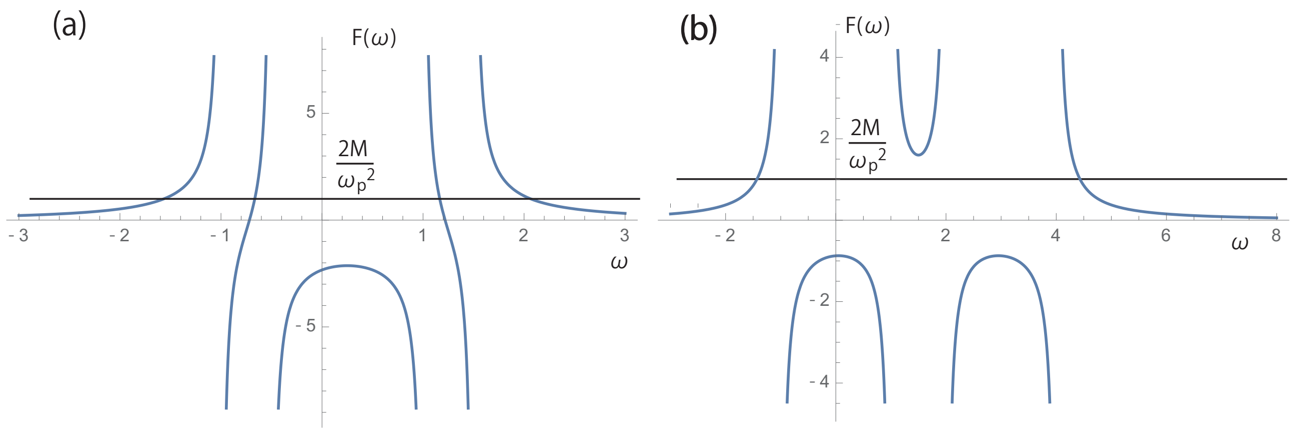

Figure 1. The profiles of $F(\omega)$ for electron-positron pair plasma in the cases, (a) $v_0 = 0.5 < c_i + c_e$ and (b) $v_0 = 3 \ge c_i + c_e$ with the parameters: $M = m = 1, c_i = c_e = 1, v_0 = 0.5, \omega_p = 1.41$. The cross point of the curve of $F(\omega)$ and the line $F = \frac{m+M}{\omega_p^2}$ gives the dispersion relation. In the case of (a) $c_i + c_e > v_0$, all solutions of the dispersion relation are real number. In the case of (b) $c_i + c_e \le v_0$, only two solutions of the dispersion relation are real number and two complex solutions exist.