Effect of Magnetic Field on the Formation and Properties of Ion-Acoustic Double Layers in Space Plasmas

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We study how an external magnetic field affects ion-acoustic double layers (DL) in a plasma with adiabatic ions and two electron populations, using the Sagdeev approach. Results show that stronger magnetic fields and oblique propagation suppress DL amplitude and width and shift the critical Mach number. This reveals how geomagnetic-field effects constrain DL formation and particle acceleration in space environment.

1.) Introduction

Electrostatic double layers are key structures responsible for charged-particle acceleration in space plasmas [1, 2]. In this work, we study the effect of magnetic field on the formation and Properties of Ion-Acoustic Double Layers in Space Plasmas in a magnetized plasma composed of cold positive ions and two populations of nonextensive electrons by the Sagdeev analysis.

2.) Basic Equations

Using the fluid equations, the normalized basic equations of ion-acoustic double layer in the considered plasma medium are [1, 3]:

$$\partial N_i/\partial\tau + \partial(N_i u_{ix})/\partial X + \partial(N_i u_{iy})/\partial Y = 0, \quad (1)$$

$$\partial u_{ix}/\partial\tau + (u_{ix}\,\partial/\partial X + u_{iy}\,\partial/\partial Y)u_{ix} = -\partial\phi/\partial X, \quad (2)$$

$$\partial u_{iy}/\partial\tau + (u_{ix}\,\partial/\partial X + u_{iy}\,\partial/\partial Y)u_{iy} = -\partial\phi/\partial Y + \Omega\, u_{iz}, \quad (3)$$

$$\partial u_{iz}/\partial\tau + (u_{ix}\,\partial/\partial X + u_{iy}\,\partial/\partial Y)u_{iz} = -\Omega\, u_{iy}, \quad (4)$$

$$\partial^2\phi/\partial X^2 + \partial^2\phi/\partial Y^2 = N_{ec} + N_{eh} - N_i. \quad (5)$$

Also, the normalized cold and hot electron densities are:

$$N_{ec} = \delta_c\,(1 + (q_c - 1)\phi)^{((q_c + 1)/2(q_c - 1))} \quad (6)$$

$$N_{eh} = \delta_h\,(1 + T_{ch}\,(q_h - 1)\phi)^{((q_h + 1)/2(q_h - 1))} \quad (7)$$

For studying the arbitrary amplitude IADLs, we use the Sagdeev pseudopotential approach, which preserves the complete complexity of the localized nonlinear structures. In the analysis, each dependent variable in Eqs. (2)-(5) is transformed into a single independent variable in a moving frame of reference, denoted by ξ, where $\xi = \alpha X + \beta Y - M\tau$ (where M is the normalized pulse propagation velocity, and α, β are the direction cosines along the x and y directions, respectively; thus, α2+β2 = 1).

Integrate Eqs. (1)-(4) by using appropriate boundary conditions for localized perturbations, we obtain the Sagdeev equation:

$$(1/2)\,(d\phi/d\xi)^2 + V(\phi) = 0 \quad (8)$$

where V is the Sagdeev potential. Using V and its second derivative to phi, allowable region of Mach number can be determined which is a necessary parameter in our numerical investigation.

3.) Numerical Results and discussions

The plasma parameters were selected from the data provided in Refs. [2, 4].

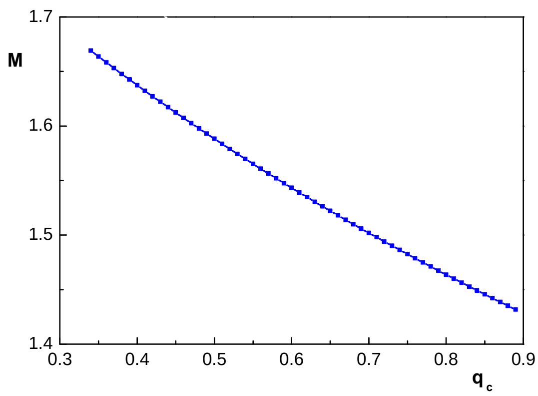

Fig. 1. Effect of nonextensive index on the Mach number of the propagated IADL.

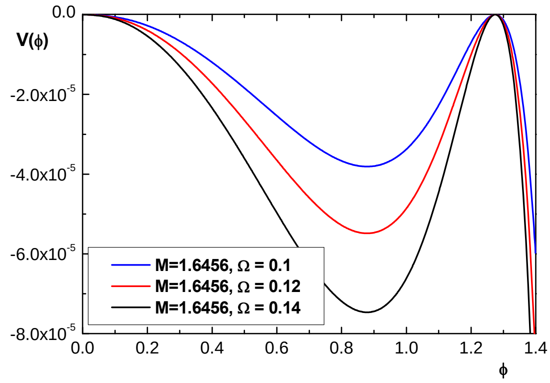

Fig. 2: Effect of magnetic field **Ω** on the IADLs.

4.) Conclusion

Using fluid model and numerical methods, effect of magnetic field on the properties of IADLs in a magnetized plasma with nonextensive electron species was investigated. It was shown that the normalized pulse propagation velocity decrease by increasing the nonextensive index of electrons. Also, it was found that the magnetic field only affects the width of IADLs and it does not have any effect on the amplitude of them.

4.) References

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