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ORIGINAL ARTICLE

Current-driven solitons and shocks in plasmas having non-Maxwellian electrons

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Abstract The current-driven electrostatic solitons and shocks are investigated in flowing plasmas having stationary dust and non-Maxwellian electrons. The propagation of solar wind parallel to the external magnetic field in the boundary regions of dusty magnetospheres of planets can give rise to drift type unstable electrostatic waves and nonlinear structures even if density is homogeneous. These waves can be produced in laboratory plasma experiments as well. Here the theoretical model is applied to Saturn's magnetosphere.

Keywords Current-driven instabilities · Non-Maxwellian plasmas · Sheared flow driven mode

1 Introduction

A theoretical model has been proposed to study the new type of drift-like electrostatic waves and instabilities which develop as a result of background inhomogeneous current in magnetized plasmas (Saleem 2011a). It shows that the sheared flow of electrons and ions in the presence of stationary dust produces electrostatic drift-like wave even if density of the plasma is homogeneous. Such waves and instabilities can also appear in electron ion plasmas if sheared flow velocities of both species are not the same. On the other hand, in the presence of heavy dust, such waves and instabilities can occur even if the flow velocity of both electrons and ions is the same. Since the solar wind is structured and has local sheared flows (Gosling et al. 1972; Hundhausen 1973), therefore at the edge regions of Saturn's dusty magnetosphere these unstable waves can be produced where the solar wind is locally parallel to the planetary magnetic field. Similar situation can be achieved in laboratory experiments as well. In this model, it is assumed that the local equilibrium has been reached with the background sheared flow of electrons and protons in the presence of stationary dust. The zero order inhomogeneous current twists the ambient magnetic field and it becomes space dependent. The inhomogeneous magnetic field plays the similar role in producing this wave as density gradient does in producing usual low frequency drift wave. However, in this case the available free energy in the form of sheared flow of plasma species can give rise to unstable electrostatic perturbations. It has also been proposed that the nonlinear dynamics can give rise to dipolar vortices (Saleem 2011b) in dusty magnetospheres of planets and comets. Recently (Saleem et al. 2012), this model has been applied to Jupiter's magnetosphere.

The present work predicts that the short scale electrostatic solitons and shocks are produced as a result of solar wind interaction with the dusty magnetosphere of Saturn in the region where the solar wind flows almost parallel to the planet's magnetic field. But we have noticed that the nonlinear structures in such environments will have very large scales contrary to the results mentioned in Saleem et al. (2012). The usual drift waves (D'Angelo 1963; Chen 1964, 1965) exists due to density gradient and it forms nonlinear structures like vortices (Hasegawa and Mima 1978), solitons (Salat and Plasma 1991) and shocks (Tasso 1967).

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