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Excitation of ion acoustic waves and formation of nonlinear structures in O-H plasma of upper ionosphere

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Low frequency electrostatic ion acoustic waves (IAWs) in the upper ionosphere have been detected by Freja satellite [1] and many others. Nonlinear electrostatic structures in the form of solitons, shocks, double layers, and vortices have also been observed by this satellite between the altitudes of 600 km to 1700 km in the auroral region of upper ionosphere [2]. In the magnetized plasma of ionosphere, field-aligned and cross-field flows are the sources of free energy for the waves to grow [3]. If the shear in ions field-aligned flow is positive then a purely growing instability takes place in the plasma under certain conditions and in this case IAW does not propagate [4]. On the other hand if shear in flow is negative then dispersion relation of IAW is modified and phase velocity of the wave shifts away from the region of heavy Landau damping even for the plasma which has ion temperature Ti closer to electron temperature Te.

Using plasma kinetic approach, a theoretical model has been presented to explain the existence of IAWs in the ionosphere. It shows that the parallel electron current gives rise to unstable IAWs in the pure oxygen plasma of ionosphere in the presence of field-aligned ions shear flow [5]. Ionosphere consists of several kinds of ions at different altitudes and it is important to consider the effects of protons on the wave dynamics.

In this investigation, oxygen-hydrogen plasma of upper ionosphere is studied in the presence of ions field-aligned shear flow and parallel electron current. It is pointed out that purely growing shear flow driven instability becomes an oscillatory instability in the two ion component plasma and hence it gives rise to IAWs in the framework of multi-fluid theory. In the case of negative shear in the parallel flow velocity of ions, the linear dispersion relation of IAWs is modified and instability does not take place. But in this case, plasma kinetic theory predicts that the growth rate of electron parallel current-driven IAWs turns out to be larger than the Landau damping in hot ion plasma. Presence of hydrogen ions in oxygen plasma introduces two time scales of these low frequency electrostatic waves. Both fluid and kinetic theories show that IAWs are excited in oxygen-hydrogen plasma of upper ionosphere at different frequencies and wavelengths due to ions field-aligned shear flow and by electron parallel current [6].

Nonlinear dynamics of these electrostatic waves in the presence of ions shear flow have been investigated in the F-region ionosphere [7]. The hump solitons are formed when electrons are thermalized and they obey Maxwell density distribution. In the presence of energetic electrons, the density dips are also formed which is in agreement with the observations. Here the effects of non-Maxwell electron distribution function on the amplitude and width of electrostatic solitons are pointed out.

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