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Damped KP equation for magnetosonic waves in a dissipative ionospheric F Layer OH plasma

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In this work, we investigate the linear and nonlinear dynamics of magnetosonic waves in a dissipative Oxygen-Hydrogen (OH) ionospheric F layer plasma. It is shown that these waves can propagate nonlinearly as solitary structures for both super and sub, acoustic and Alfvenic regimes. We use the hyperbolic tangent method to solve the collisional Kadomtsev-Petviashvili (KP) equation and obtain a damped solitary wave solution. Both compressive and rarefactive damped solitary structures are obtained. The dependence on various parameters oxygen ion-neutral collisional frequency, temperature, propagation angle, and ambient magnetic field present in the Earth's ionosphere F region is shown.

Multi-ion plasmas are known to exist in a variety of situations, both in the laboratory and in naturally occurring space plasmas. Applications of multi-ion plasmas were carried out theoretically and experimentally in a cylindrical plasma column and in ionospheric plasmas where the effects of a terrestrial magnetic field were taken into account [1]. Various low frequency modes were investigated under such study. The existence of multi-ion plasmas has been confirrmed by various satellite (e.g. Viking, Freja, IMAGE) observations [2]. The F-layer of the terrestrial ionosphere situated at 500-800km is ionized by Sun' UV radiations consisting of various gases such as N_2, O_2, and atomic oxygen undergoes ionization. The region of the F-layer below 800 km is partially ionized gas consisting of ionized oxygen, protons, electrons and neutrals. Oxygen hydrogen (OH) plasma known as bi-ion plasma is an active area of investigation and many studies have considered different linear and nonlinear modes propagating in such plasmas.

In the presented work, we are going to discuss the formation of 2D nonlinear magnetosonic waves in an OH collisional ionospheric plasma. In ionospheric plasmas, collisions between the neutrals and charged particles become important. The linear and nonlinear analysis of the damped Kadomtsev Petviashvilli (DKP) equation is done.

To describe the 2D nonlinear propagation of magnetosonic waves in a partially ionized plasma, we will set up the basic set of equations 1) a single fluid equation [3] from the equations of motion for the electrons, hydrogen ions, oxygen ions, and neutrals fluids, 2) magnetic induction equation from the continuity equation and Maxwell's equations by incorporating Ohm's law. We are considering F-layer of the ionosphere in slab geometry and the ambient magnetic field is configured in the xy-plane such that $\mathbf{B_0}$ makes a small angle with the propagation vector. In order to obtain linear dispersion relation, we take the propagation vector '**k**' along the x-axis and the perturbations in the magnetic field are taken in the y-direction only. By using a plane wave solution of the form$\sim$ $e^{i(kx-\omega t)}$, we obtain an appropriate linear dispersion relation and expressions for propagation frequencies for collisional magnetosonic waves.

By using well-known reductive perturbation technique, we derived the nonlinear evolution equation for magnetosonic waves in two dimensions and found its analytical solution by following the hyperbolic tangent method given by Demiray [4]. In the absence of collisions we get the standard KP equation. We noted here that the collisional terms are taken on the slow time scale only and are of the order of $\varepsilon^{3/2}$. We have analyzed the two-dimensional magnetosonic wave by using the parameters for oxygen-ion plasma present in the F-layer of the ionosphere. In the F-layer, the magnetic eld is of the order of 0.5×10^{-5}T, temperature range is 800–2600 K, range of density of charged particles is $10^{11}-10^{12}m^{-3}$, oxygen gyro-frequency range is 230-300 s^{-1}. Our analytical solution describes the propagation of fast magnetosonic wave with positive root and slow magnetosonic wave with negative root appearing in the dispersion relation before the radicand.

The investigations of analytical results confirm the existence of super Alfvenic and supersonic rarefactive solitary structures for the positive root (fast magnetosonic wave) of normalized phase velocity. In the case of the negative root of normalized phase velocity (slow magnetosonic wave) sub Alfvenic and sub sonic compressive solitary structures exist [5]. But below a certain temperature limit, depending on other parameters, no solitary structure is obtained. These nonlinear structures show significant variations with different plasma parameters and decay on the temporal scale.

We feel that our theoretical model is general enough to be easily extended from the bi-ion case to a multi-ion case and should have applications to not only the case of ionospheric plasma but also in other plasmas such as those of molecular clouds.

References

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