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ORIGINAL ARTICLE

Nonlinear evolution of inertial Alfvén wave turbulence

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Abstract Some recent experimental observations have been shown that inclusion of electron collisions damping in inertial Alfvén wave (IAW) dynamics may be important for laboratory as well as space plasmas. This paper presents the numerical simulation of model equation governing the nonlinear dynamics of IAW in low-beta plasmas. When the nonlinearity arises due to the ponderomotive force and Joule heating driven density perturbations, the model equation turns out to be a modified nonlinear Schrödinger equation (MNLS). The electron collisions are introduced only in the electron momentum equation. The damped localized structures of IAW with sidebands are obtained. Also, the effect of collisional damping on power spectra of magnetic fluctuations with different scaling laws has been studied. These turbulent structures may be responsible for particle acceleration in laboratory and space plasmas.

Keywords Alfvén waves · Turbulence · Collisional damping

1 Introduction

Dispersive Alfvén waves (DAW) are identified in following two extreme limits for low-$\beta(<1)$ plasmas: $\beta < m_e/m_i$ and $\beta > m_e/m_i$; where β is thermal pressure to background magnetic pressure ratio, m_e/m_i is the electron to ion mass ratio. In $\beta < m_e/m_i$ regime, the wave is known as "inertial" Alfvén wave (IAW), while in the other regime $\beta > m_e/m_i$, it is termed as "kinetic" Alfvén waves (KAWs). It has been studied by many authors, but infact, a nice description of dispersive Alfvén waves was discussed by Lysak and Lotko (1996).

A comparison of results obtained from observational data and theoretical model has been studied by Chymrev et al. (1988). They observed that the nonlinear evolution of Alfvén waves results in vortex structures. On the basis of satellite (IC-B-1300) data, they observed the variation of perpendicular components of electric field suggested a vortex like character of the wave. Also, they have studied the wave character based on theoretical model using kinetic theory. The numerical results of drift electron equations were also showing the solitary structure of Alfvén waves. Shukla and Stenflo (1995) have studied the nonlinear properties associated with Alfvén wave. The density perturbation as a result of ponderomotive force may lead modulational instability, filamentation instability and vortex structures of Alfvén wave. The DAW can nonlinearly interact with very low-frequency electrostatic or electromagnetic perturbations, giving rise to an envelope of DAWs whose dynamics is governed by a nonlinear Schrödinger equation. In the present manuscript also, the nonlinear properties of IAW are studied by the numerical simulation of nonlinear Schrödinger equation.

IAWs are known to be very important because of their associated parallel electric field, in laboratory and space plasmas (Kletzing et al. 2010; Ergun et al. 2005; Stasiewicz et al. 2000; Goertz and Boswell 1979; Kletzing 1994). They transport electromagnetic energy, may accelerate plasma particles, and are produced in large, dense, magnetized laboratory plasmas or in almost any space plasma environment where there are changes in plasma currents or magnetic field configuration. IAW is a short-wavelength shear Alfvén mode that has been proposed by some authors as a possible acceleration mechanism for producing auroral electrons. In

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