Nonlinear whistler wave propagation in bi-Maxwellian plasmas

N.N. Rao\textsuperscript{a}, P.K. Shukla\textsuperscript{b}

\textsuperscript{a} Theoretical Physics Division, Physical Research Laboratory, Navrangpura, Ahmedabad 380009, India
\textsuperscript{b} Institut f"{u}r Theoretische Physik – IV, Fakult"{a}t f"{u}r Physik und Astronomie, Ruhr-Universit"{a}t Bochum, D-44780 Bochum, Germany

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Abstract

The coupling between electron whistlers and nonlinear ion-acoustic density fluctuations in a plasma with bi-Maxwellian distributed electrons is considered by including the combined effects of relativistic electron-mass variation and ponderomotive force nonlinearities. The coupled mode propagation is governed by a generalized system of Schrödinger-Boussinesq equations, which admits localized exact analytical solutions for stationary propagation. Parameter regimes for the existence of different types of soliton solutions are discussed. © 1999 Elsevier Science B.V.

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1. Introduction

Whistlers are one of the earliest and extensively studied naturally occurring modes in space plasma environments such as the magnetosphere, the bow-shock and the solar wind, and they have found applications in explaining a host of diverse phenomena [1–5]. For example, low-frequency electromagnetic fluctuations such as the “one-hertz” waves found in the upstream regions of the solar wind have been attributed to the excitation of whistlers by shock waves in the presence of bi-Maxwellian distributed electrons [6]. On the other hand, it is well known that plasmas having electron species with different temperatures, also called the two-electron-temperature (TET) plasmas, possess a normal mode structure which is quite novel and unusual when compared with that of the usual plasmas with single electron species. For example, while even a small fraction of cold electron species introduces substantial changes in the dispersive characteristics of linear ion-acoustic waves [7], the formation of finite amplitude coherent structures such as solitons, shocks and double layers in the nonlinear regime is significantly affected by the presence of the second species [8–12]. Temperature anisotropy arises also in the laboratory devices such as the tokamaks when the confined plasma is heated by means of a cyclotron resonance mechanism [13].

In recent years, there has been renewed interest in the study of whistlers in the nonlinear regime [1,2,14,15]. In particular, Karpman et al. [15] have investigated the nonlinear evolution of the modulational instability associated with the whistler modes, and the consequent formation of envelope solitary waves. Numerical work on whistlers propagating parallel to the background magnetic field shows [16] that the mode propagation is non stochastic, thereby indicating the possible existence of integrable parameter regimes for the mode propagation. Recently, we have shown [17] that the coupled propagation of