

## Solution of the Perturbed Zakharov-Kuznetsov (ZK) Equation Describing Electron-Acoustic Solitary Waves in a Magnetized Plasma

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A theoretical investigation is carried out for obliquely propagating higher-order dispersion electron-acoustic solitary waves (EASWs) in a magnetized collisionless plasma consisting of a cold electron fluid and non-thermal hot electrons obeying a non-thermal distribution, and stationary ions. For nonlinear EASWs waves, a reductive perturbation method was employed to obtain the Zakharov-Kuznetsov (ZK) equation. It was found that the present plasma model supports rarefactive EASWs solitons. When the wave amplitude increases, the width and velocity of the wave deviate from the prediction of the ZK equation. This means that we have to extend our analysis to solve the perturbed (ZK) equation with a fifth-order dispersion term. The higher-order solution for the resulting equation has been achieved via what is called the perturbation technique. The effects of the external magnetic field and the obliqueness are found to significantly change the higher-order properties of the EASWs. The present investigation can be of relevance to the electrostatic solitary structures observed in various space plasma environments.

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### I. INTRODUCTION

Electron acoustic waves (EAWs) are one of the fundamental nonlinear wave phenomena appearing in plasma physics. EAWs have been observed when the plasma consists of two species of electrons with different temperatures, referred to as hot and cold electrons, and have been well studied both in laboratory [1] and in space environments [2–3]. Several theoretical attempts have been made to explain the propagation of EASWs in an unmagnetized plasma [4–7]. Noticeably, in practice, the hot electrons may not follow a Maxwellian distribution, due to the formation of phase space holes caused by the trapping of hot electrons in a wave potential. Accordingly, in most space plasmas, the hot electrons follow the trapped/vortex-like distribution [8–9]. It is worth noting that electron trapping is observed not only in space plasmas, but also in laboratory experiments [10]. Recently, energetic electron distributions were also observed in the different regions of the magnetosphere. Cairns *et al.* [11] used a non-thermal distribution of electrons to study the ion acoustic solitary structures observed by the FREJA satellite. It was shown that solitons with both positive and negative density perturbations could exist. Singh and Lakhina [12] derived the Sagdeev pseudopotential for electron-acoustic waves in an unmagnetized three component plasma and studied the effect of the non-thermal electron distribution on the nonlinear electron-