



Ain Shams University
Faculty of Science
Department of Physics

***Investigation of Nonlinear Waves Structures
In Magnetized Plasmas***

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By

Lamyaa Samir Hassen Ebrahim

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Name : *Lamyaa Samir Hassen Ebrahim*

Thesis Advisors Approved

Prof. Dr. Mostafa Mohammed Shalaby

Prof. of Theoretical Physics
Department of Physics - Faculty of Science - Ain Shams University

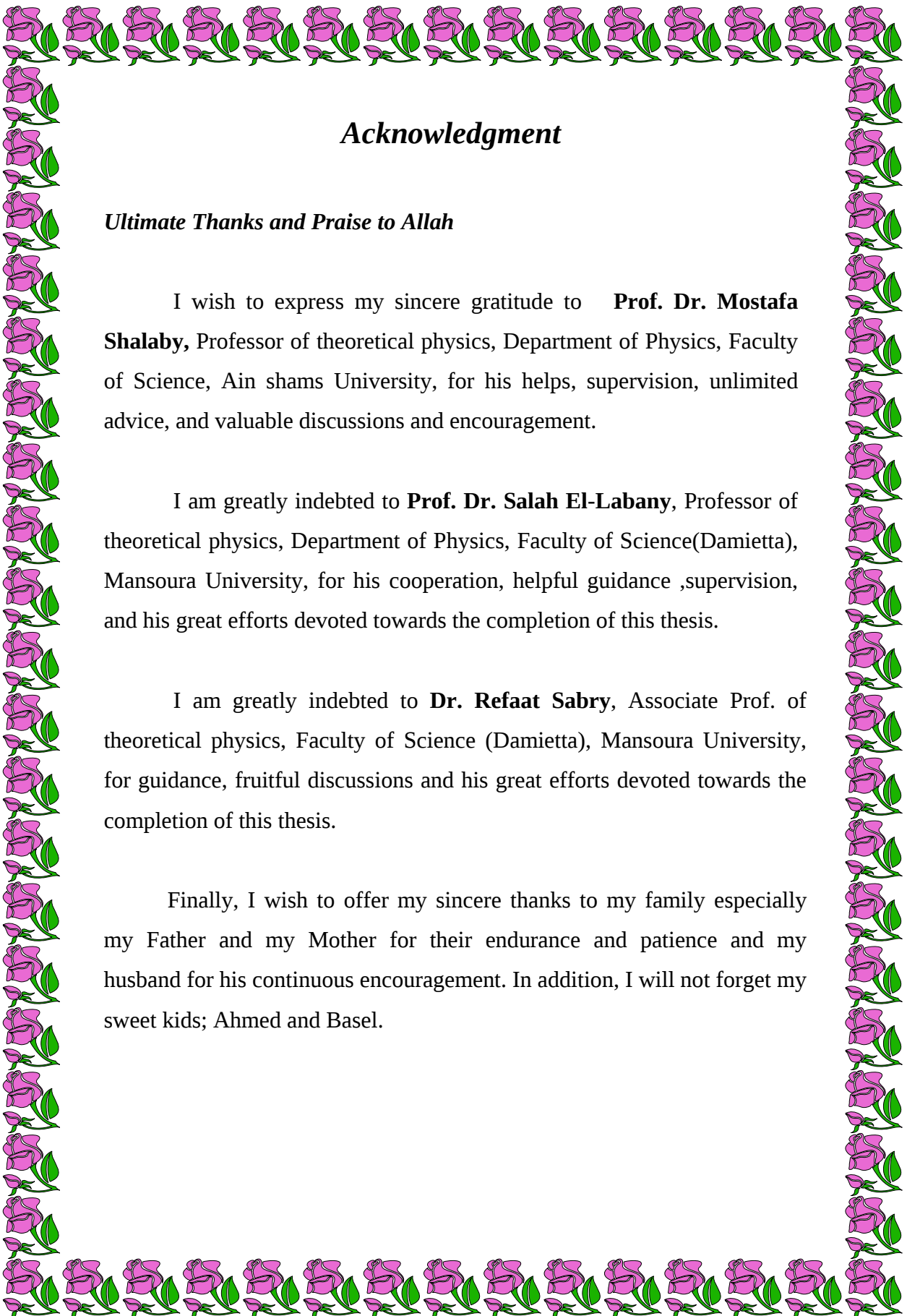
Prof. Dr. Salah Kamel El-Labany

Prof. of Theoretical Physics
Department of Physics -Faculty of Science (Damietta), Mansoura University

Dr. Refaat Sabry

Associate Prof. of Theoretical Physics
Department of Physics Faculty of Science (Damietta), Mansoura University

(2012)



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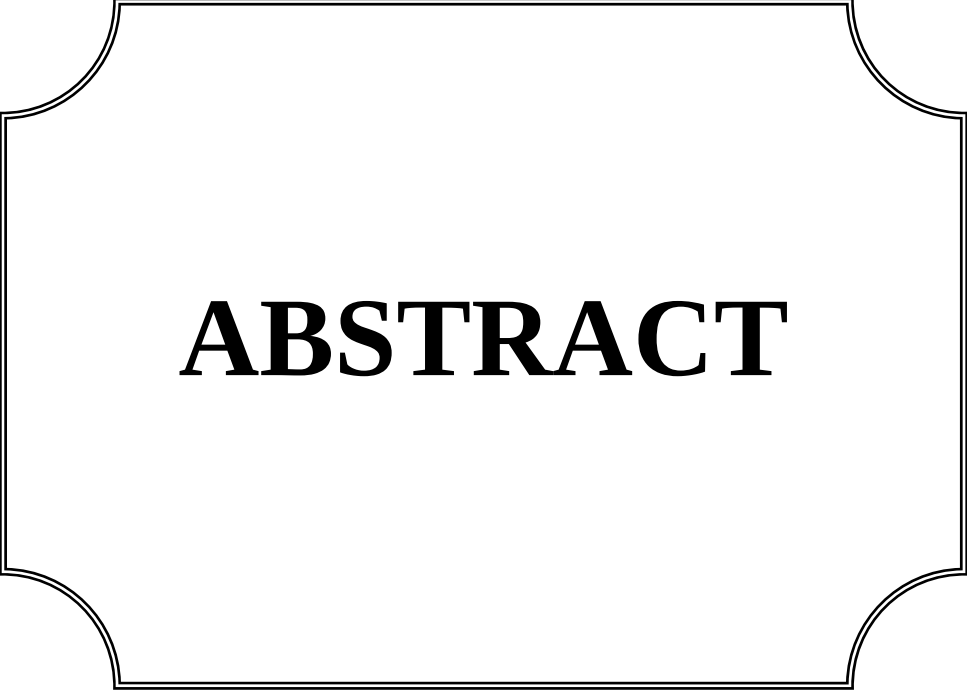
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ABSTRACT

Abstract

Theoretical investigation is carried out for understanding the properties of three-dimensional electron-acoustic waves (i.e., solitary waves and double-layers) propagating in magnetized plasma whose constituents are cold magnetized electron fluid, hot electrons obeying nonthermal distribution, and stationary ions.

For this purpose, the hydrodynamic equations for the cold magnetized electron fluid, nonthermal electron density distribution, and the Poisson equation are used to derive the corresponding nonlinear evolution equation; Zakharov-Kuznetsov (ZK) equation, in the small- but finite- amplitude regime.

The ZK equation is solved analytically and it is found that it supports both solitary and blow-up solutions. It is found that rarefactive electron-acoustic solitary waves strongly depend on the density and temperature ratios of the hot-to-cold electron species, as well as the nonthermal electron parameter. Furthermore, there is a critical value for the nonthermal electron parameter, which decides whether the electron-acoustic solitary wave's amplitude decreases or increases by changing various plasma parameters. Importantly, the change of the propagation angles leads to miss the balance between the nonlinearity and dispersion; hence the localized pulses convert to explosive/blow-up pulses. However, The ZK equation is not appropriate to describe the system at the critical vicinity of plasma compositions. Therefore, the reductive perturbation stretching is changed to overcome such difficulty and a modified ZK (MZK) is derived.

The MZK equation is analyzed to examine the existence regions of the solitary pulses and double-layers. It is found that rarefactive electron-acoustic solitary waves and double-layers strongly depend on the density and temperature ratios of the hot-to-cold electron species as well as the nonthermal electron parameter.

Both of ZK and MZK equations are investigated in the light of Viking satellite observations of nonlinear structures pertaining to the dayside auroral zone plasmas.

An investigation for the generation of ion-acoustic rogue waves in a collisionless, unmagnetized electro-negative plasma is carried out. For this purpose, a reductive perturbation theory (i.e., derivative expansion technique) is used to obtain a nonlinear Schrödinger equation (NLS equation) for an arbitrary frequency of the carrier wave.

The critical wave-number threshold (i.e., which indicates where the modulational instability sets in) has been determined precisely for various regimes. The rule of the negative ion densities and masses on the modulational instability profiles and growth rates corresponding to different negative ion mass groups in Titan's atmosphere (i.e., according to the Cassini Spacecraft observations) is carried out.

At the critical wavenumber threshold, a random perturbation of the amplitude grows and thus creates ion-acoustic rogue waves. Such nonlinear structure, as reported here, could be useful for explaining highly energetic pulses in Titan's atmosphere.

CHAPTER (I)

Introduction

CHAPTER (1)

INTRODUCTION

1.1- Definition of Plasma

Plasmas occur pervasively in nature: indeed, most of the known matter in the Universe is in the ionized state, and many naturally occurring plasmas, such as the surface regions of the Sun, interstellar gas clouds and the Earth's magnetosphere, exhibit distinctively plasma-dynamical phenomena arising from the effects of electric and magnetic forces. The science of plasma physics was developed both to provide an understanding of these naturally occurring plasmas and in furtherance of the quest for controlled nuclear fusion.

Any ionized gas cannot be called plasma; of course there is always some small degree of ionization in any gas. A useful definition of plasma is as follows: plasma is a ***quasineutral*** gas of charged and neutral particles which exhibits a ***collective behavior***.

Here we will define "*quasineutral*" and "*collective behavior*". Firstly, the plasma is "*quasineutral*"; that is, neutral enough so that one can take the density of positive ions (n_{i+}) partially equals to the density of negative ions (n_{i-}), $n_{i+} \approx n_{i-} \approx n$, where n is a common density called the plasma density, but not so neutral that all the interesting electromagnetic forces vanish. We mean by "*collective behavior*" the motions that depend not only on local conditions but also on the state of plasma in remote regions as well, Chen (Chen 1974).

1.2- Waves in Plasmas

An ionized gas is capable of a wide variety of oscillatory motions, which can in general be exceedingly complex. The subject of waves in plasmas is important not only because the natural dynamical motions of plasmas often lead to waves but also because waves are often used to excite, perturb, or probe plasmas. Waves are also important because they carry energy from the surface of plasma (where the waves may have been excited) into the bulk of the plasma, where the waves may be absorbed and, for example, heat the plasma. The study of the propagation, linear and nonlinear, of electrostatic and electromagnetic waves constitutes a large portion of the discipline of plasma physics.

A broad range of wave frequencies is detected in space, from less than few cycles per hour to several million cycles per second. Disturbances on stars, our sun, solar wind, shocks, magnetospheres, and ionosphere all contribute to the generation of such waves.

Waves in plasmas are an interconnected set of particles and fields which propagate in a periodically repeating fashion. Plasma is an electrically conductive quasineutral fluid. In the simplest form, it is composed of electrons and of positive ions, but it may also contain multiple ion species including negative ions, positrons or dust particles and neutral particles etc. Due to its collective behavior, a plasma couples to electric and magnetic fields. This complex medium of particles and fields supports a wide variety of waves. Studies of these waves in plasmas are very beneficial for plasma diagnostics, because the wave modes of plasma depend on the plasma characteristics.

Waves in plasmas can be classified as electromagnetic or electrostatic according to whether or not there is an oscillating magnetic field. Applying Faraday's law of induction to plane waves, we find $k \times \tilde{E} = \omega \tilde{B}$, implying that an electrostatic wave must be purely longitudinal, while an electromagnetic wave must

have a transverse component, but may also be partially longitudinal. Both classes have been detected in space (Parks 1991).

Waves can be further classified by the oscillating species. In most plasmas of interest, the electron temperature is comparable to or larger than the ion temperature. This fact, coupled with the much smaller mass of the electron, implies that the electrons are much faster than the ions. An electron mode depends on the mass of the electrons, but the ions may be assumed to be infinitely massive, i.e. stationary. An ion mode depends on the ion mass, but the electrons are assumed to be massless and redistribute themselves instantaneously according to the Boltzmann relation (Chen 1974) . Only rarely, e.g. in the lower hybrid oscillation, will a mode depend on both the electron and the ion mass. The various modes can also be classified according to whether they propagate in an unmagnetized plasma or parallel, perpendicular, or oblique to the stationary magnetic field. Finally, for perpendicular electromagnetic electron waves, the perturbed electric field can be parallel or perpendicular to the stationary magnetic field. Since plasma, is a complex medium it can also support the nonlinear waves. Such nonlinear effects combine to produce wave like disturbances that are not of the form given above and interesting phenomena such as solitary waves, double layers, vortices etc., are frequently observed in laboratory, space and astrophysical plasmas (Parks 1991, Shukla and Mamun 2002).

1.3- Plasma Applications

Plasma science has, in turn, spawned new avenues of basic science. Most notably, plasma physicists were among the first to open up and develop the new and profound science of chaos and nonlinear dynamics.

Plasma physicists have also contributed greatly to studies of turbulence, important for safe air travel and other applications. Basic plasma science continues to be a vibrant research area. Recent new discoveries have occurred in

understanding extremely cold plasmas which condense to crystalline states, the study of high-intensity laser interactions, new highly efficient lighting systems, and plasma-surface interactions are important for computer manufacturing.

Because plasmas are conductive and respond to electric and magnetic fields and can be efficient sources of radiation, they are used in a large number of applications where such control is needed or when special sources of energy or radiation are required. Of course we do not always have to make a plasma in order to study one (i.e., for example see Figure 1.1). The Sun is plasma; so are the Van Allen radiation belts surrounding the Earth. The solar wind is streaming plasma that fills the solar system. These plasmas in our solar system provide many unsolved mysteries.

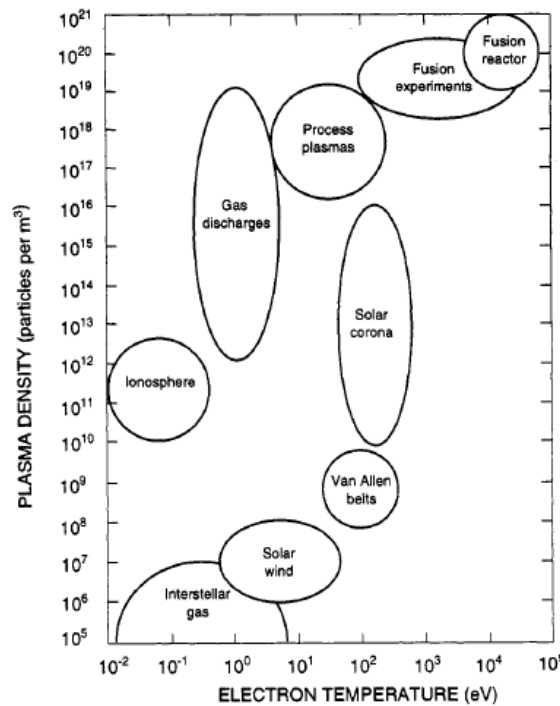


Figure 1.1 Typical parameters of naturally occurring and laboratory plasmas (Goldston and Rutherford 1995).