Astrophys Space Sci (2013) 346:279–284
DOI 10.1007/s10509-013-1429-y

ORIGINAL ARTICLE

# Vortex formation in nonlinearly coupled modes in a magnetized quantum plasma

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Received: 18 October 2012 / Accepted: 24 March 2013 / Published online: 26 April 2013


**Abstract** Linear and nonlinear properties of coupled modes in a magnetized quantum plasma in the presence of electron Fermi pressure are studied in a nonuniform magnetoplasma composed of electrons, ions, and extremely massive and negatively charged immobile dust grains. Stationary solutions of the nonlinear equations that govern the dynamics of coupled modes are presented. It is found that electrostatic dipolar vortex structure can form in such a plasma. The dipolar structures in dense plasmas are observed to be formed on a much shorter scalelength by comparison with their classical counterparts. It is found that the increasing Fermi temperature shortens the scalelength over which the nonlinear coherent structures are formed. The relevance of the present investigation with regard to the dense astrophysical plasmas is also pointed out.

**Keywords** Electrostatic waves · Inhomogeneous plasmas · Coupled modes · Vortices

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## 1 Introduction

Quantum plasmas have attracted a lot of attention owing to their potential applications in many situations of interest such as microelectronic devices (Markowich et al. 1990), dense astrophysical environments (Jung 2001; Opher et al. 2001) (for instance, white dwarfs and neutron stars), high density laser-matter interaction experiments (Marklund and Shukla 2006) as well as dusty plasmas (Shukla and Ali 2005; Masood et al. 2007; Khan et al. 2008). The two approaches that have been most frequently used to describe the statistical and hydrodynamic behavior of charged species at quantum scales in dense plasmas are the Wigner-Poisson and the Schrödinger-Poisson models. These two approaches are the quantum equivalent of kinetic and fluid treatments of classical plasmas, respectively. The two approaches have been discussed in some detail by Manfredi (2005). The quantum hydrodynamic (QHD) model is based on the Schrödinger-Poisson formulation. It has been extensively applied to study the linear and nonlinear propagation of several waves in the quantum plasma (Marklund et al. 2005; Masood and Mushtaq 2008; Haas et al. 2003; Haas 2005).

Owing to the ubiquity of dusty plasmas in nature, there has been a lot of interest among the plasma physics community to study these systems in the past two decades. The dusty plasma is a normal electron-ion plasma with an additional component of extremely massive and highly charged (negatively or positively charged depending upon the background conditions) dust particles. The large mass of the dust-grains by comparison with ions and electrons introduces new scale lengths in the system which are non-existent in an ordinary electron-ion plasma. It is well known that in dusty plasma, there are two normal modes of unmagnetized, weakly coupled plasmas, namely the dust acoustic (DA) and dust ion acoustic (DIA) modes, respectively. These modes