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ORIGINAL ARTICLE

The instability of two non-parallel plasma shells in quantum plasma

H. Mehdian · A. Hasanbeigi · K. Hajisharifi

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Abstract The instability of two non-relativistic non-parallel electron-proton plasma shells in quantum plasma is investigated when the perturbation wave propagates perpendicular to the direction of one of the shells. It is assumed that the ions are not affected by the perturbation. The full three-dimensional dispersion tensor is derived by the fluid-Maxwell equations and the dispersion equation has been solved numerically. It is shown that two kinds of instability, the two-stream instability and the filamentation instability, may occur in the system. The effects of the angle between two plasma shells on the growth rate of instabilities and the cut-off wave number have been illustrated.

Keywords Plasma shell · Streaming instability · Quantum plasma · Cut-off wave number

1 Introduction

Beam-plasma systems involving more than two species are relevant in a number of astrophysical scenarios. For instance, collisionless shocks may arise from colliding e^+e^-/e^+e^- (Spitkovsky 2008) or e–p/e–p (Martins et al. 2009; Bret and Perez Alvaro 2011) plasma shells. When two collisionless plasma shells propagate in plasma, two important kinds of streaming instability, two-stream instability (TSI) (Anderson et al. 2002; Haas et al. 2000, 2003a, 2003b) and filamentation instability (FI) (Bret and Haas 2011; Bret 2007a, 2008), can appear in the system. The filamentation instability, which leads to the generation of large-scale magnetic fields, has a wide range of applicability to astrophysical and space plasmas. So far, these instabilities have usually been studied for parallel streams in low density regime (Lazar et al. 2006; Tabak et al. 1994; Ruhl et al. 1999) while astrophysics offers a very wide range of unstable systems. A. Bret designs a good question, why should real systems systematically fit this parallel streams (Bret 2009). Therefore, our paper is based on two plasma shells colliding over a background of plasma at an arbitrary angle. Presenting of background plasma is very important to design this problem because one can be sitting in the reference frame of one of the shells to cancel any orientation parameter. We also restrict ourselves to the plasma systems in a dense astrophysical environment. Under this circumstance, the quantum effects are expected to play a significant role in the behavior of charged particles.

The field of quantum plasma is becoming of increasing current interest motivated by its potential applications in dense plasma areas, such as in fusion setting and astrophysical phenomena (Brodin et al. 2007; Harding and Lai 2006; Azechi et al. 2006; Li et al. 2005; Manfredi and Hervieux 2007; Salamin et al. 2006; Mourou et al. 2006; Calvayrac et al. 2000; Stenflo et al. 2006; Becker et al. 2006). In planetary interiors and in compact astrophysical objects, such as the interiors of super dense white dwarfs and the atmospheres of neutron stars, one would have the dense quantum plasmas. In dense plasmas, electrons are degenerate and one encounters the electron quantum force involving the quantum Bohm potential. In this paper, we suppose that the quantum force acting on the electrons dominates over the quantum statistical pressure, which amount to assum-

H. Mehdian (✉) · A. Hasanbeigi · K. Hajisharifi
Department of Physics and Institute for Plasma Research, Kharazmi University, 49 Dr Mofatteh Avenue, Tehran 15614, Iran
e-mail: mehdian@tmu.ac.ir

A. Hasanbeigi
e-mail: hbeigi@tmu.ac.ir

A. Hasanbeigi
e-mail: ahbeigi@gmail.com