Astrophys Space Sci (2013) 345:119–124
DOI 10.1007/s10509-013-1385-6

ORIGINAL ARTICLE

Langmuir dark solitons in dense ultrarelativistic electron-positron gravito-plasma in pulsar magnetosphere

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Received: 6 December 2012 / Accepted: 2 February 2013 / Published online: 14 February 2013

Abstract Nonlinear propagation of electrostatic modes in ultrarelativistic dense elelectron-positron gravito-plasma at the polar cap region of pulsar magnetosphere is considered. A nonlinear Schrödinger equation is obtained from the reductive perturbation method which predicts the existence of Langmuir dark solitons. Relevance of the propagating dark solitons to the pulsar radio emission is discussed.

Keywords Electron-positron plasma · Langmuir solitons · Pulsar magnetosphere

1 Introduction

Pulsars are celestial sources that believe to be rotating neutron stars producing light-house like beams of radio emissions from the magnetic poles. As shown by Goldreich and Julian (1969) the rotating magnetic dipole produces a quadrupole electric field whose component parallel to the open magnetic field lines at the poles extracts particles very effectively from neutron star surface and accelerates them to highly relativistic energies. Thus, the magnetosphere is filled with plasma which shields the electric field. Complete shielding is established when the net charge reaches n_{GJ}—the Goldreich-Julian charge density. The Lorentz factors of the accelerated particles reach about 10^6 and they emit hard curvature radiations that propagate at a sufficient angle to the magnetic field, so that significant pair production of electron-positron can occur (Erber 1966). It is commonly accepted that the newly created particles produce more pairs by emitting energetic synchrotron or curvature radiation. As a result an avalanche of secondary particles populates the magnetosphere with densities $10^4 n_{GJ}$ (Ruderman and Sutherland 1975). Here, we extend our earlier research on pulsar microstructure, soliton formation, wakefield accelerations, gravitational waves, and growing modes (Mofiz et al. 1985, 2011; Mofiz and Podder 1987; Mofiz and Mamun 1992; Mofiz, Mofiz 1989, 1990, 1997, 2007, 2009) to account the pair ultrarelativistic pressure and the gravity

The paper is organized as follows. Section 2 describes the fluid model of the dense ultrarelativistic electron-positron plasma under gravity. Considering a Lorentz invariant frame moving with group velocity of the wave, a Nonlinear Schrödinger Equation (NLSE) is derived using the reductive perturbation method (Gardner and Morikawa 1960). A linear dispersion relation is obtained showing the existence of Langmuir waves under gravity and with ultrarelativistic temperature for wave propagation. The solution of NLSE shows the generation of Langmuir dark solitons. Results are discussed in Sec. 3. Finally, Sec. 4 concludes the paper.

2 The mathematical model

We consider two-fluid magnetohydrodynamic (MHD) equations to describe the electron-positron plasma in the pulsar magnetosphere of the neutron star. The equations are the usual continuity and momentum balance equations for the plasma species, electrons and positrons, supplemented by the Poisson's equation for electrostatic wave propagation.

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