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ORIGINAL ARTICLE

Magnetosonic cylindrical soliton in electron-positron-ion plasma

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Abstract Solutions in the form of cylindrical magnetosonic solitons of compression and rarefaction were obtained within the scope of the three-species electromagnetic gas-dynamic model of an electron-positron-ion plasma. These solutions can describe formation of cylindrical structures in accretion disks and jets in the vicinity of compact astrophysical objects.

Keywords Electron-positron-ion plasma · Cylindrical magnetosonic soliton · Accretion disk · Jet

1 Introduction

In the recent years scientific interest to the electron-positron-ion plasma (epi-plasma) is constantly growing. Only in the 21 century more then a hundred of papers devoted to this topic were published. Such interest is explained by the significant progress achieved in the observational astrophysics. It results in discovery and active study of such extraordinary compact objects as magnetars (strongly magnetized neutron stars with magnetic field up to 10^{14}–10^{16} Gauss), relativistic jets released from active galactic nuclei etc. The advances of the theoretical plasma physics also contributed into more profound understanding of the processes in the vicinity of the discovered objects.

The magnetosphere of neutron stars is considered to be filled with epi-plasma. The presence of the electrons and positrons in such magnetosphere is due to the instability of vacuum in a super-strong magnetic field. The ions originate from some interior source, for example, as a result of evaporation or seismic processes on surface of a star or come from outside in the process of accretion (Beloborodov and Thompson 2007).

Jets are lengthy highly collimated fluxes of relativistic epi-plasma (over 1000 kpc long and approximately 1 pc in diameter) formed in the vicinity of neutron stars (Zheleznyakov and Koryagin 2002, 2005; Derishev et al. 2007). In such jets the ion fraction depends on the distance between the place of jet launch is to the accretion disk. It is assumed that the accretion discs consist of epi-plasma as well (Moslem et al. 2007).

The examples mentioned above demonstrate how important is to study nonlinear structures which could occur in epi-plasma. Solitons, shock waves, vortices, compact bunches (clusters) and jets are omnipresent among compact astrophysical objects. There are a few scientists who try to describe these phenomena using three-species models. For example, eager attention has been drawn to surface waves (Tsintsadze 1998; Cho and Lee 2003); double layers (Kakati and Goswami 2000; Mishra et al. 2007; Ghosh and Bharuthram 2008); localized electromagnetic waves (Berezhiani et al. 1994; Shatashvili and Rao 1999); electromagnetic vortices and vortices of different nature (Haque et al. 2002; Haque and Saleem 2003; Azeem and Mirza 2004); ion-acoustic solitons (Popel et al. 1995; Nejoh 1996; Shatashvili et al. 1997; Salahuddin et al. 2002; Dubinov and Sazonkin 2009); Alfven solitons (Kakati and Goswami 1998; Saleem and Mahmood 2003); magnetosonic solitons (Mushtaq and Shah 2005; Takahashi et al. 2008) and others.

As for accretion disks and jets, axis-symmetric non-linear structures such as cylindrical solitons demand close scrutiny. There are numerous papers dedicated to the study of non-plane cylindrical and spherical electro-static solitons in various plasmas (for instance, Maxon and Viecelli 1974a; Sahu

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