8th Asia-Pacific Conference on Plasma Physics, 3-8Nov,2024 at Malacca

Spin Dynamics in Rotating Quantum Plasmas: Coupled EPI Dispersion and Solitary wave analysis

Punit Kumar and Atherv Saxena

Department of Physics, University of Lucknow, India
e-mail (speaker) : punitkumar@hotmail.com

In recent years, there has been significant interest in exploring quantum plasmas in astrophysical environments. In these highly dense, rotating settings, quantum mechanical effects become significant when the de-Broglie wavelength of charged particles approaches inter-particle spacing, and when the Fermi temperature exceeds the system temperature, causing the plasma to behave like a Fermi gas [1-2]. Unique attributes of quantum plasma arise from factors such as fermionic pressure laws, electron tunnelling, and Bohr magnetization. The quantum Bohm potential modifies the dispersion of collective modes, particularly at quantum scales, influenced by plasma densities and Fermi temperatures [3]. Multi-component quantum plasmas, consisting of electrons, positrons, and ions, are found in environments such as active galactic cores [4], pulsar magnetospheres [5], black hole accretion discs [6], and the early universe [7]. The Quantum Hydrodynamic (QHD) model has been used to describe these systems, leading to insights into ion-acoustic solitary and shock waves [8]. A detailed bifurcation analysis of quantum ion-acoustic waves in degenerate plasma has been conducted [9-10]. Novel approaches treat electrons and positrons as distinct fluids, focusing on magnetosonic waves in e-p-i quantum plasma [11-12], while the unique characteristics of e-p plasmas differentiate them from conventional electron-ion systems [13-17].

This paper studies the dynamics of uniform astrophysical quantum plasma consisting of electrons, ions, and positrons under the influence of an external electromagnetic wave, analysing Ion Acoustic Solitary waves and soliton solutions. It begins with an overview of electron-ion-positron (e-p-i) plasma, highlighting its importance in dense astrophysical environments shaped by external magnetic fields. The Separated Spin Evolution Quantum Hydrodynamic (SSE-QHD) model is introduced as the analytical framework, incorporating quantum diffraction, quantum statistical effects, and separated spin-up and spin-down effects for fermions. The paper analyses the dispersion relation for coupled ion, electron, and positron modes considering various quantum effects and environmental influences. It also investigates the solitary wave structures due to ion acoustic waves and their solutions using the KdV method.

The results indicate that plasma wave transmission exhibits an inverse correlation with the magnitude of the normalized propagation vector, indicating decreased transmission efficiency as vector magnitude increases due to intensified plasma interaction with higher photon energy, leading to accelerated energy loss. Quantum plasma, characterized by greater wave dispersion compared to classical plasma, attributes this phenomenon to the presence of Fermi pressure. Additionally, spin-polarization amplifies power transmission of waves, notably increasing the propagation vector in fully polarized plasma scenarios. Integration of quantum correction terms, such as Fermi pressure, quantum Bohm potential, and spin effects, elevates electrostatic potential within soliton profiles in quantum plasma compared to classical plasma counterparts. These corrections induce energy redistribution and heightened electron occupancy in higher energy states, fortifying soliton stability and dynamics. Furthermore, variations in ion particle density influence the electrostatic potential of soliton profiles, with increasing density correlating with decreased electrostatic potential, driven by altered forces and charge redistribution influenced by Fermi pressure and quantum effects. This study provides insights into the behaviour of electron-positron plasmas in extreme environments, advancing our understanding of the universe's most energetic and enigmatic phenomena.

This work is supported by SERB, India through Matrics grant no. MTR/2021/000471

References

[1] Q. Haque, S. Mahmood, and A. Mushtaq, "Phys. Plasmas," vol. 15, p. 082315, **2008**.
[2] R. Sabry, W. M. Moslem, F. Haas, S. Ali, and P. K. Shukla, "Phys. Plasmas," vol. 10, p. 3858, **2003**.
[3] S. Balberg and S. L. Shapiro, "arXiv:astro-ph/0004317v2," **2000**.
[4] H. R. Miller and P. J. Witta, Active Galactic Nuclei. Springer, **1987**.
[5] F. C. Michel, "Theory of pulsar magnetospheres," Reviews of Modern Physics, vol. 54, pp. 1–66, **1982**.
[6] L. Stenflo, P. K. Shukla, and M. Marklund, "New low-frequency oscillations in quantum dusty plasmas," Europhysics Letters, vol. 74, pp. 844–846, **2006**.
[7] W. Misner, K. Thorne, and J. A. Wheeler, Gravitation. Freeman, **1973**.
[8] N. Ghosh and B. Sahu, Communications in Theoretical Physics, vol. 71, no. 2, pp. 237–242, **2019**.
[9] Q. Haque, Results in Physics, vol. 18, no. 103287, pp. 1–6, **2020**.
[10] Saha, B. Pradhan, and S. Banerjee, European Physical Journal Plus, vol. 135, no. 216, pp. 1–13, **2020**.
[11] Z. Iqbal, I. A. Khan, T. H. Khokhar, and G. Murtaza, IEEE Transactions on Plasma Science, vol. 49, no. 7, pp. 2063, **2021**.
[12] Saha and S. Banerjee, Dynamical Systems and Nonlinear Waves in Plasmas. CRC Press, **2021**.
[13] F. B. Rizatto, "J. Plasma Phys.," vol. 40, p. 288, **1988**.
[14] M. Y. Yu, "Astrophys. Space Sci.," vol. 177, p. 203, **1985**.
[15] F. Verheest, M. A. Hellberg, G. J. Gray, and R. L. Mace, "Astrophys. Space Sci.," vol. 239, p. 125, **1995**.
[16] Mushtaq and H. A. Shah, "Phys. Plasmas," vol. 12, p. 072306, **2005**.
[17] Kourakis, F. Verheest, and N. Cramer, "Phys. Plasmas," vol. 14, p. 022306, **2007**.