Abstract

Plasma is a collection of statistically large number of interacting free electrons and ionized atoms or molecules, which exhibit the properties of quasineutrality and collective behaviour. These particles interact among themselves due to their respective fields, and also due to the free energy. This free energy arises as a result of the disturbances in the medium by the action of different perturbative agents that naturally influence the system. Traditionally, we usually deal with plasma having low density and high temperature, known as the classical plasma. However, there exists another branch of plasma physics that deals with high particle density and low temperature. This branch is popularly known as the quantum plasma physics. When the interparticle distance becomes of the order of de-Broglie wavelength, $\lambda_B = \hbar / mv$*, quantum effects start playing a dominant role. The existence of quantum plasma is naturalistically found in compact astroobjects like white dwarfs, brown dwarfs, neutron stars, and so on. The compiled thesis herein is mainly centered on the gravitational instability, and different modes of plasma acoustic waves and instabilities excitable in compact astrophysical objects and their circumvent atmospheres.*

In ***Chapter 1****, we present a brief overview of plasma. The genesis of plasma physics is highlighted. The different branches of applicability of plasma physics are mentioned. A detailed distinction between classical and quantum plasma is summarily presented. The existence of large scale quantum plasmas in terms of the stellar evolutionary pathway leading to the formation of compact astrophysical objects is briefly described. We highlight the onset of acoustic waves and instabilities in plasmas. The importance of studying waves and instabilities in compact astrophysical objects is described. We finally outline the motivation and objectives of the directional compiled study. The basic methodological framework used to fulfill the objectives is also briefly presented.*

In ***Chapter 2****, we investigate the Jeans instability excitation dynamics in strongly correlated astrofluid media in a vast spherically symmetric volume. A normal spherical mode analysis over the perturbed medium yields a quadratic dispersion relation. It is specifically shown that the effect of geometrical curvature introduces a compound viscous influence onto the dispersion relation. A numerical illustrative platform is*

provided to see the various fluid stabilizing and destabilizing factors against the gravity. Astronomical implications and applications of our findings are summarily actualized.

In ***Chapter 3****, a theoretic model is presented to investigate the dynamics of the nucleus-acoustic waves in rotating self-gravitating electrostatically confined degenerate quantum plasma system in spherically symmetric geometry is constructed. The model consists of heavy nuclear species, lighter nuclear species, and quantum degenerate electronic species. It specifically considers the influences of the Bohm potential, Coriolis rotation, viscoelasticity, and electrostatic confinement pressure. A standard normal spherical mode analysis gives a generalized dispersion relation (septic). A numerical illustrative platform is used to analyze the influence of different plasma parameters, like nuclear charge-to-mass coupling parameter, heavy-to-light nuclear charge density ratio, and Coriolis rotation on the nucleus-acoustic wave growth behaviours. The analysis presented herein has correlations and consistencies in the growth backdrop of various compact astroobjects and their circumvent atmospheres.*

In ***Chapter 4****, we propose a relativistic quantum plasma model to analyze the ion-acoustic mode stability in gyromagnetoactive spherical electron-ion plasma in a compressible quantum hydrodynamic fabric. It co-includes the Coriolis force, magnetic field, Bohm potential, etc. A spherical mode analysis yields a unique form generalized linear dispersion relation (quartic) with atypical coefficients. The impact of equilibrium number density, magnetic field, and Coriolis rotation on the ion-acoustic mode instability is investigated. The atypical growth features, so-explored herein, are further justifiably confirmed in the colourspectral fabric in light of the existing illustrative reports in the literature. The practical realization of the analysis is presented at the end.*

In ***Chapter 5****, we analyze the propagatory nucleus-acoustic wave modes excitable in the completely degenerate cores of the ONe (oxygen-neon) and CO (carbon-oxygen) white dwarfs and in their nearly degenerate envelopes. We consider a three-component spherical plasma system consisting of non-thermal quantum electrons, classical thermal light nuclear species, and classical thermal heavy nuclear species. Our systematic exploration emphasizes on the transition state between the thermodynamical temperature (classical) and the Fermi temperature (quantum) for the borderline regions of intermediate degeneracy. A normal spherical mode analysis yields a sextic generalized linear dispersion relation. It clearly highlights the plasma*

multiparametric dependency of the hybrid nucleus-acoustic wave features. A numerical illustrative platform is constructed to investigate the full nucleus-acoustic wave propagatory and dispersive behaviours. It could be hopefully useful to see the quantum interaction processes of compact astroobjects.

In ***Chapter 6****, we employ a quantum hydrodynamic model to investigate the cylindrical acoustic waves excitable in a gyromagnetoactive, viscous, self-gravitating cylinder rotating with a constant angular velocity along the longitudinal direction. The two component plasma model comprises of electrons and ions, governed by their appropriate equations of state. A standard normal cylindrical wave analysis, employing Hankel function is applied for the first time to obtain a generalized sextic dispersion relation. The obtained dispersion relation in the low-frequency regime is then analyzed under four parametric windows, namely the quantum non-planar, quantum planar, classical non-planar, and classical planar regimes. Influence of different realistic parameters like equilibrium number density, kinematic viscosity, and so forth on the instability dynamics is investigated by means of a numerical illustrative platform. The presented analysis may be useful in determining the cylindrical acoustic wave dynamics of astrophysical objects like starburst rings, filamentary structures, magnetized arms of spiral galaxies, and so on.*

In ***Chapter 7****, all the obtained results and conclusions from the semi-analytic investigations carried out to fulfill the aims and objectives of the compiled thesis are briefly highlighted . The futuristic scopes and possible refinements in this direction, both from the perspective of theoretical modelling and asteroseismic probes are finally mentioned.*

Keywords. *Quantum plasma, hydrodynamics, Jeans instability, nucleus-acoustic waves*